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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	32796
First Inventor or Application Identifier	Hidetoshi Narahara
Title	METHOD OF ANALYZING ELECTROMAGNETIC...
Express Mail Label No.	EL633643622US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
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Washington, DC 20231

1. [X] * Fee Transmittal Form *(e.g., PTO/SB/17)*
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2. [X] Specification [Total Pages 206]
(preferred arrangement set forth below)
- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings *(if filed)*
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. [X] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 128]

4. Oath or Declaration [Total Pages 4]
a. [X] Newly executed (original or copy)
b. [] Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 16 completed)*
i. [] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [] Microfiche Computer Program *(Appendix)*

6. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
a. [] Computer Readable Copy
b. [] Paper Copy (identical to computer copy)
c. [] Statement verifying identity of above copies

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ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [X] Power of Attorney
9. [] English Translation Document *(if applicable)*
10. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations
11. [] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
13. [] * Small Entity Statement(s) *(PTO/SB/09-12)* [] Statement filed in prior application, Status still proper and desired
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17. CORRESPONDENCE ADDRESS

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PATENT

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Attorney Docket No. 32796

Assistant Commissioner for Patents
Box PATENT APPLICATION
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Sir:

Transmitted herewith for filing by other than a small entity is the patent application of:

Inventor: Hidetoshi Narahara, Seijirou Kojima, Hiroyuki Tsujikawa, Kenji Shimazaki, and Kasumi Hamaguchi

For: METHOD OF ANALYZING ELECTROMAGNETIC INTERFERENCE

128 sheets of informal drawings are included.

An assignment of the invention to Matsushita Electric Industrial Co., Ltd. is included along with a Recordation Form Cover Sheet. Please record and return the assignment to the undersigned.

Priority is claimed under 35 U.S.C. §119 on the basis of the following foreign applications:

Japanese Patent Application No. Hei. 11-196190 Filed July 9, 1999

A certified copy of this application will be forwarded.

An Information Disclosure Statement is enclosed.

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CLAIMS AS FILED

For	Number		Rate	Fees
Total claims in excess of 20:	8	×	$18.00	$144.00
Independent claims in excess of 3:	0	×	$78.00	$0.00
Multiple dependent claims, if any, add surcharge of $260.00:				$.00
Non English Specification, add surcharge of $130.00:				$.00
			Basic Fee	$690.00
			TOTAL FILING FEE	$834.00
Assignment Recordal Fee of $40.00				$40.00
			TOTAL FEE	**$874.00**

A check in the amount of the Total Fee calculated above is enclosed.

The Commissioner is hereby authorized to charge any fees under 37 C.F.R. §§1.16 and 1.17 which may be required during the entire pendency of this application, or to credit any overpayment, to Deposit Account No. 16-0820, Order No. 32796.

Respectfully,

PEARNE & GORDON LLP

David E. Spaw, Reg. No. 34732

Date: July 7, 2000

METHOD OF ANALYZING ELECTROMAGNETIC INTERFERENCE

Background of the Invention

1.Field of the Invention

The present invention relates to a method of analyzing electromagnetic interference (EMI), and more particularly, to a method of analyzing electromagnetic interference arising in a large-scale, high-speed LSI (large-scale integrated circuit) by means of high-speed, highly-accurate logic simulation.

2.Desariptionof the related Art

As is often the case, in the field of computers, LSIs find a broadening range of applications, from communications devices, such as cellular phones, to general household products, toys, and automobiles. Electromagnetic interference arising in such a product induces radio interference noise to arise in a receiver, such as a TV set or a radio, or faulty operations of another system. In order to prevent this problem, the entirety of a product is shielded, or filters are provided in a product. With a view towards preventing an increase in the number of components and cost and difficulty in preventing occurrence of electromagnetic interference in a product, strong demand exists for suppression of noise in an LSI alone.

Under such a situation, an LSI is ranked as a key device for any product which contains an LSI. Demand exists for an larger-scale, high-speed LSI for ensuring competitiveness of a product. In a situation in which the cycle of product development becomes shorter, design-automation of an LSI is indispensable for satisfying the demand. There is growing necessity for adopting synchronous circuit as a condition for introducing a state-of-the-art design-automation method. In a case where all circuits of a large-scale, high-speed LSI operate synchronously with a reference clock signal, instantaneously-changing current becomes very large, which induces an increase in electromagnetic interference.

The present invention relates to a simulation method which enables evaluation of EMI indispensable for reducing electromagnetic interference while maintaining a tendency toward a larger-scale, higher-speed LSI.

Noise imposed on another device by an LSI is roughly classified into two types; radiation noise, and conduction noise. Radiation noise emanated directly from an LSI includes noise emitted from internal wires of an LSI. However, internal wires do not act as an antenna of large size. As a matter of course, it is considered that the noise emitted directly from an LSI will pose a problem in

the future, in association with an improvement in the operation frequency of an LSI. However, as of now, the noise emitted from the inside of an LSI is considered trivial.

In contrast, conduction noise affects another device mounted on a printed board by way of direct interconnections, such as internal wires of an LSI, lead frames, or wiring patterns provided on a printed wiring board. Noise is emitted from such interconnections while the interconnections are taken as the source of origination or as an antenna. The antenna constituted of the interconnections is much larger than that constituted by internal wires of an LSI and is a dominant element in terms of electromagnetic emission.

A power line and a signal line can act as paths along which conduction noise developing in an LSI travels. In consideration of an electromagnetic field in the vicinity of an LSI, noise which results from variation in an electric current of a power source being emitted from a power line serving as an antenna is considered to be dominant. There may be a case where a ringing overshoot stemming from variation in a signal poses a problem. However, there more frequently arises a case where variation in an internal power level of an LSI propagates as a signal waveform, to thereby presents a problem. Noise

emitted from a power line or a signal line is considered to have a strong correlation with variation in the electric current of a power source (hereinafter referred to as a "source current").

A source current of a CMOS circuit will now be described by reference to a simple inverter circuit. In a case where variation arises in a voltage applied to an inverter circuit, there flows a load capacitance charge/discharge current, which is the primary source current of the CMOS circuit. In addition, a short circuit current flows together with the load capacitance charge/discharge current. In design of such a CMOS circuit, all circuits of an LSI are synchronized in accordance with constraints on the use of a design-automation tool. As a result of all circuits being synchronized, all circuits of the LSI operate simultaneously, and a peak current arises in a power source in synchronism with a reference clock signal. Further, in order to increase operating speed, or shorten a cycle, of the LSI, the capacitance of a transistor is increased so as to enable a charging/discharging operation to be completed within a short period of time. Eventually, a peak current increases. As a matter of course, the total source current of an LSI is increased even when the scale of an LSI is increased. Thus, the peak current of the power

source is increased, thereby inducing occurrence of an abrupt change in a source current. Such an abrupt change induces an increase in higher harmonic components, thereby resulting in an increase in electromagnetic interference.

Highly-precise simulation of change in a source current, which may be said to primarily account for electromagnetic interference, is considered to be effective in evaluation of electromagnetic interference arising in an LSI.

A current simulation method for effecting transistor-level current analysis, as will be described below, has conventionally been employed.

FIG. 116 is a block diagram showing the flow of processing operations pertaining to a conventional EMI analysis method. According to this method, on the basis of layout information pertaining to an LSI to be analyzed through use of a method of analyzing an electric current of a transistor, there is performed processing pertaining to a layout parameter extraction (hereinafter referred to simply as an "LPE") step 03. Subsequently, there is performed processing pertaining to a circuit simulation step 06 for effecting simulation of a circuit on the basis of a switch-level netlist; a source-of-current modeling step 08; a source line LPE step 010; a transient analysis simulation step 012; and a FFT step 014.

Processing pertaining to each of the foregoing processing steps will now be described by reference to FIG. 116.

First, there are input data 01 pertaining to the layout of a semiconductor integrated circuit (hereinafter referred to simply as "layout data 01"), which circuit is to be subjected to EMI analysis; parameters of elements, such as transistor elements or various parasitic wiring elements (e.g., resistors and capacitors); and an LPE rule 02 for defining a form in which extracted layout parameters are to be output. In step 03, parameters of the respective elements included in the layout data 01 are calculated in accordance with the LPE rule 02, to thereby prepare a netlist 04. In step 03, parameters of parasitic elements of a power source (and the ground) are not extracted.

In step 06 are input the netlist 04 prepared in step 03 and a test pattern 05 for replicating a desired logic operation in a circuit serving as an object of analysis. There are calculated a load capacitance charge/discharge current and a short circuit current, both responding to the operating state of an internal circuit, wherewith information 07 about the waveform of an electric current of each transistor (hereinafter referred to simply as "current waveform information 07") is produced. The first operation of the processing pertaining to step 06

is effected on the assumption that the potential of a power source (and that of ground) is a variation-free, ideal potential.

In step 08, the current waveform information pieces 07 concerning the respective transistors prepared in step 06 are entered. Each of the thus-entered current waveform information 07 pieces is modeled into a mode which can be applied to subsequent step 012, wherewith information 09 concerning a source-of-current element model (hereinafter referred to simply as "source-of-current element model information 09") is prepared. According to a common method, in order to alleviate the load associated with processing pertaining to step 012 and subsequent steps, each functional circuit block consisting of a plurality of transistors is modeled as a source-of-current element.

Processing pertaining to step 010 differs from processing pertaining to step 03, only in that parameters of parasitic elements of a power source and parameters of those of parasitic elements of ground wiring (e.g., resistors, decoupling capacitance, and like elements) are extracted and subjected to EMI analysis in lieu of extracted parameters of transistor elements and extracted parameters of various parasitic wiring elements. Hence, repeated explanation of processing pertaining to step 010 is omitted. In step 010, a power source (and ground)

wiring netlist 011 is prepared.

In step 012, there are entered the source-of-current element model information 09 prepared in step 08, the power source (and ground) wiring netlist 011 prepared in step 010, and an impedance 016 (including, resistance, capacitance, and inductance) of a wire or lead frame. Through analysis of these input data carried out by a transient analysis simulator typified by SPICE, variation in the line voltage of a circuit to be analyzed is calculated, wherewith a line voltage drop result 016 is prepared.

Subsequently, processing pertaining to step 06 is performed again. In contrast with the first operation of the processing pertaining to step 06 having been effected on the assumption that the potential of the power source (and the ground) is a variation-free, ideal potential, the line voltage drop result 016 prepared in step 012 is entered, and the current waveform information pieces 07 concerning the respective transistors are prepared again in consideration of the line voltage drop. Similarly, processing pertaining to steps 08 and 012 is performed again.

Processing pertaining to steps 06, 08, and 012 is effected several times in a looped manner, wherewith there is produced a current waveform result 013 which duplicates

variation in a line voltage with high precision.

In step 014, the current waveform result 013 prepared in step 012 is entered and subjected to fast Fourier transformation (hereinafter abbreviated FFT), to thereby enable frequency spectrum analysis. There is obtained an EMI analysis result 015.

In the conventional example, the precision of verification varies greatly according to combination of processing pertaining to the LPE step 03, processing pertaining to the source line LPE step 010, and processing pertaining to the source-of-current modeling step 08. However, a certain level of accuracy of analysis can be expected. A transient analysis simulator typified by SPICE is used for transistor-level analysis of an electric current. Hence, a limitation is imposed on the level of a circuit to be analyzed, and an enormous amount of processing time is required. The level of a semiconductor integrated circuit has increased recently, and establishment of an EMI analysis method which enables high-speed analysis of an electric current on a larger scale than a transistor level by dealing with the analysis in abstract more than a transistor level dealing is desired.

A gate-level current analysis method (hereinafter referred to as a "gate-level power consumption analysis

method") has conventionally been proposed as a current analysis method which can be made faster. This gate-level current analysis method is used for analyzing power consumption.

The gate-level power consumption analysis method for estimating power consumption on a gate level comprises the following steps: namely, a step of preparing beforehand a library from the total amount of electric current required per change when a logic signal appearing at an output port of a circuit element is changed from a logic value of 0 to 1 or from a logic value of 1 to 0; and a step of adding, to a total amount of current of the entire circuit at each time, a total amount of electric current required per change when a logic signal appearing at an output port of an instance in a circuit, the circuit being an object of estimation of power consumption, is changed from a logic value of 0 to 1 or a logic value of 1 to 0, to thereby estimate the total power consumed by the overall circuit (i.e., a value obtained by means of multiplying the total amount of current by an external voltage). FIG. 109 shows the configuration of an example system for effecting the conventional, popular gate-level power consumption analysis method. The gate-level power consumption analysis system shown in the drawing is operated through use of an amount-of-current analyzer

comprising circuit connection information storage means 1001; signal pattern storage means 1002; means 1003 for storing the amount of electric current flowing through an element (hereinafter referred to simply as "element current storage means 1003"); total-amount-of-current storage means 1004; and total-amount-of-current calculation means 1005.

Individual elements constituting the gate-level current analysis system shown in FIG. 109 will now be described. Procedures for calculating the amount of current shown in FIG. 113 will be described, by reference to the gate-level circuit connection information shown in FIG. 110, a pattern of signal change arising at each terminal shown in FIG. 111, and the amount of current flowing through respective elements shown in FIG. 112.

The circuit connection information storage means 1001 stores circuit connection information concerning connection of circuits which are objects of analysis. Circuit connection information, such as that shown in FIG. 110, is stored in the circuit connection information storage means 1001 in advance. The circuit connection information is generally called a netlist.

The circuit connection information comprises an external input port D, an external clock signal input port CLK, an external output port Q, flip-flops FF1 and FF2,

a buffer element BUF1, and wires D1 and Q1 for interconnecting elements. Each of the flip-flops FF1 and FF2 comprises a data input pin D, a clock signal input pin CK, and a data output pin Q. A logic value appearing at the data input pin D immediately before arrival of a leading edge of a clock signal input to the clock input pin CK is transmitted to the data output pin Q.

The buffer element BUF1 has a data input pin A and a data output pin Y. A logic value appearing at the data input pin A is output to the data output pin Y.

The above elements have a lag, such as an intra-element lag, and permit propagation of a signal with a time lag of 1 ns. The external input port D is connected directly to the input pin D of the flip-flop FF1. The external clock input port CLK is a terminal for receiving variation in a clock signal from the outside and is connected directly to the input pin CK of the flip-flop FF1 and to the input pin CK of the flip-flop FF2. The external output port Q is connected directly to the output pin Q of the flip-flop FF2 and outputs a signal value of the flip-flop FF2. A wire D1 interconnects the output pin Y of the buffer BUF1 and the input pin D of the flip-flop FF2. A wire Q1 interconnects the output pin Q of the flip-flop FF1 and the input pin A of the buffer BUF1.

The signal pattern storage means 1002 stores a

pattern of signal change applied to information concerning connections of a circuit to be analyzed. As shown in FIG. 111, a pattern of change in a signal input to the input port CLK and a pattern of change in a signal input to the input port D shown in FIG. 110 are stored in the signal pattern storage means 1002 in advance. The horizontal axis in FIG. 110 represents the time at which change arises in a signal pattern. Upon each change, the signal pattern is changed between a logic value of 0 and a logic value of 1.

The element current storage means 1003 stores information concerning the amount of electric current flowing through an element; that is, information concerning the total amount of electric current flowing when single change arises in an external terminal of each element. Information concerning the amount of electric current flowing through an element, such as that shown in FIG. 112, is stored beforehand in the element current storage means 1003. Reference numeral 1301 designates the amount of electric current flowing through a flip-flop FF when change arises in a signal input to the clock signal input terminal CK of the flip-flop FF. Reference numeral 1302 designates the amount of electric current flowing through the flip-flop FF when change arises in a signal output from the output terminal of the flip-flop

FF. Reference numeral 1303 designates the amount of electric current flowing through the buffer BUF when change arises in a signal output from the output terminal Y of the buffer BUF.

The total-amount-of-current calculation means 1005 is given a flowchart such as that shown in FIG. 114.

In step 1501, the circuit connection information which is stored in the circuit connection information storage means 1001 and is shown in FIG. 110 is read. In step 1502, a signal pattern stored in the signal pattern storage means 1002 and shown in FIG. 111 is read. In step 1503, information concerning the amount of electric current (hereinafter referred to simply as "element current information") stored in the element current storage means 1003 and shown in FIG. 112 is read.

In step 1504, the signal pattern shown in FIG. 111 is delivered to the circuit connection information shown in FIG. 110, to thereby enable propagation of a signal. When change arises in a signal appearing at the external terminal of a circuit element written in the element current information, the amount of electric current flowing through the external terminal is added to the information concerning the total amount of electric current at each time. A signal propagation method used herein is identical with a signal propagation method

employed in a timing simulator. More specifically, the method is to calculate, in time sequence, change arising in a real circuit in accordance with a given signal pattern by means of tracking circuits which are affected by the signal pattern. The signal propagation method employed in a timing simulator is generally embodied in the form of a plurality of commercial tools. Hence, detailed description of the signal propagation method is omitted. FIG. 112 shows change in a logic value of a signal appearing at each pin, which has been caused as a result of propagation of the signal pattern in each step.

FIG. 112 shows change in a logic value in the same form as that in which the signal pattern is shown in FIG. 111. After completion of propagation of the signal, in step 1505 the information concerning the total mount of electric current calculated at respective times shown in FIG. 113 is stored in the total-amount-of-current storage means 1004. The total-amount-of-current storage means 1004 stores the information concerning the total amount of electric current detected at respective times according to the foregoing procedures, in the form shown in FIG. 113.

In a case where information concerning the total amount of electric current is calculated in greater detail, a load dependence coefficient of a current which is dependent on an output load capacitance (or on a charge

current) and the total amount of electric current which is not dependent on an output load capacitance (or on a short circuit current) are stored in an element current storage section. Thereafter, information concerning the capacitance of each wiring (i.e., capacitance information) is read, the sum of the load-independent and the product of the capacitance information and the load dependence coefficient is taken as the total amount of electric current. As described above, according to the conventional gate-level power consumption calculation method shown in FIG. 110, the amount of electric current flowing upon a single change arising in a signal appearing at an input or output pin is taken as a unit or as flowing momentarily. In other words, the conventional method determines only the total amount of electric current. In terms of power consumption, the accuracy of the thus-calculated total amount of current is sufficient. However, EMI analysis requires information concerning chronological change in electric current, and the total amount of electric current is not sufficient in terms of EMI analysis.

The conventional example using the transistor-level current analysis method can be expected to yield a certain level of accuracy. However, a transient analysis simulator typified by SPICE is used for transistor-level

current analysis. A limitation is imposed on the level of a circuit to be analyzed, and an enormous amount of processing time is required. The scale of a semiconductor integrated circuit has increased recently, and establishment of an EMI analysis method which enables high-speed analysis of an electric current at a larger level than a transistor level is desired.

In the conventional example using the gate-level current analysis method, high-speed analysis of a current is feasible. However, only the total amount of electric current is determined. The gate-level current analysis method is sufficient in terms of power consumption but in sufficient in terms of EMI analysis.

Summary of the Invention The present invention has been conceived to solve the drawbacks of the conventional methods and is aimed at providing a method for enabling valuation of electromagnetic interference in an LSI through simulation within a realistic period of time.

To this end, an EMI analysis method according to the present invention is characterized by means of adding a function of highly precisely analyzing a change in power current to a high-speed gate-level simulation.

The present invention provides an electromagnetic interference analysis method for analyzing the amount of electromagnetic interference arising in an LSI by means

of performing a logic simulation, the method comprising:

an instantaneous current calculation step of calculating the amount of instantaneous electric current from event information, the information being produced when a change arises in a signal and including the instance name of each cell in which the change has arisen, the name of the signal, a time at which the change has arisen, and transition information;

a modeling step of modeling the instantaneous electric current according to a predetermined rule; and

an FFT processing step of subjecting to fast Fourier processing (hereinafter referred to as "FFT processing")the information concerning a change in electric current, the information being calculated through a modeling step. Here, the amount of instantaneous current means the amount of electric current induced by an event. The amount of electric current flowing through a cell when a change arises in an output of the cell as an event is taken as the amount of instantaneous electric current.

Preferably, the modeling step includes an averaging step of averaging the instantaneous current over a certain discrete width, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being produced by the

averaging step.

Preferably, the modeling step includes a rectangular waveform modeling step of modeling the instantaneous current as a rectangular waveform whose height is calculated for information for each event such that the area of the rectangular waveform becomes equal to the amount of electric current of each event, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the rectangular waveform modeling step.

Preferably, the modeling step includes a geometrically-similar rectangular waveform modeling step of modeling the instantaneous current as a geometrically-similar rectangular waveform whose height and width are calculated such that the area of the rectangular waveform becomes equal to the amount of electric current of each event, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the geometrically-similar rectangular waveform modeling step.

Preferably, the modeling step includes a rectangular waveform modeling step of calculating the instantaneous electric current for information for each event, and a step

of modeling the instantaneous current as a rectangular waveform through use of the amount of electric current and a table representing the relationship between the width and height of a rectangular waveform, to thereby subject to FFT processing the information concerning a change in electric current calculated in the rectangular waveform modeling step.

Preferably, the modeling step includes a step of calculating the instantaneous electric current for information for each event, and a rectangular waveform modeling step of modeling the instantaneous current as a rectangular waveform through use of a slew in input waveform and a table representing the relationship between the width and height of a rectangular waveform, to thereby subject to FFT processing the information concerning a change in electric current calculated in the rectangular waveform modeling step.

Preferably, the modeling step includes a step of calculating the instantaneous electric current for information for each event, and a rectangular waveform modeling step of modeling the instantaneous current as a rectangular waveform through use of an output load capacitance and a table representing the relationship between the width and height of a rectangular waveform, to thereby subject to FFT processing the information

concerning a change in electric current calculated in the rectangular waveform modeling step.

Preferably, the modeling step includes a step of calculating a drop in voltage from the amount of electric current flowing in each cell and the resistance of a power and correcting the amount of instantaneous electric current of each cell for each event, on the basis of the relationship between the drop in voltage and the amount of instantaneous electric current.

Preferably, the modeling step includes a step of calculating a drop in voltage from the amount of electric current flowing in each cell, the resistance of a power line, and the capacitance of an on-chip capacitor, and correcting the amount of instantaneous electric current of each cell for each event, on the basis of the relationship between the drop in voltage and the amount of instantaneous electric current.

Preferably, the modeling step includes a step of transiently-analyzing a power RC of each cell and a cell power source, accurately calculating a drop in voltage, and a correction step of correcting the amount of instantaneous electric current of each cell for each event, on the basis of the relationship between the drop in voltage and the amount of instantaneous electric current.

Preferably, the modeling step includes a triangular

waveform modeling step of modeling the instantaneous current as a triangular waveform which has a given width and whose height is calculated for information for each event such that the amount of instantaneous electric current becomes equal to the area of the triangular waveform, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the triangular waveform modeling step.

Preferably, the modeling step includes a multi-order-function waveform modeling step of modeling the instantaneous current as a multi-order-function waveform, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the multi-order-function waveform modeling step.

Preferably, the modeling step includes a exponential function waveform modeling step of modeling the instantaneous current as an exponential-function waveform, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the exponential-function waveform modeling step.

Preferably, the modeling step includes a step of modeling the amount of instantaneous electric current

while separating the same into a short circuit electric current component and a charge current component.

Preferably, the modeling step includes a calculation step of calculating the height of a rectangular waveform from a library in which peak currents of cells are characterized according to the type of cell, and a rectangular waveform modeling step of modeling the amount of instantaneous electric current as a rectangular waveform, the peak current calculated in the calculation step being taken as the height of the rectangular waveform and the area of the triangular waveform being equal to the amount of electric current of each event, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the rectangular waveform modeling step.

Preferably, the calculation step includes a step of calculating a peak current for each cell from information concerning a slew in the cell, by reference to a library in which the relationship between a slew in input waveform and a peak current is characterized in the form of a table according to the type of cell.

Preferably, the calculation step includes a step of calculating a peak current for each cell from information concerning a load capacitance of a cell, by reference to

a library in which the relationship between a load capacitance and a peak current is characterized in the form of a table according to the type of cell.

Preferably, the calculation step includes a step of setting a plurality of peak currents for a composite cell and calculating the heights of a plurality of rectangular waveforms through use of a characterized library, and the rectangular waveform modeling step corresponds to a step of modeling the amount of electric current into a plurality of rectangular waveforms.

Preferably, the calculation step includes a step of setting a plurality of peak currents for each of the rise and fall of a flip-flop (FF) cell and calculating the heights of a plurality of rectangular waveforms through use of a characterized library, and the rectangular waveform modeling step corresponds to a step of modeling the amount of electric current into a plurality of rectangular waveforms.

Preferably, the calculation step includes a step of calculating the height of a rectangular waveform through use of a library in which peak currents are characterized, in consideration of the state of an input signal.

Preferably, the modeling step includes

a step of calculating a drop in voltage from the amount of electric current determined according to the

type of cell and from the resistance of a power line; and

a correction step of characterizing, for each cell, the relationship between a drop in voltage and the amount of instantaneous electric current in the form of a table, to thereby correct the amount of instantaneous electric current for each event of the cell.

Preferably, the modeling step includes

a step of calculating a drop in voltage from the amount of electric current determined according to the type of cell, the resistance of a power line, and the capacitance of an on-chip capacitor; and

a correction step of characterizing, for each cell, the relationship between a drop in voltage and the amount of instantaneous electric current in the form of a table, to thereby correct the amount of instantaneous electric current for each event of the cell.

Preferably, the correction step includes a step of iterating several times calculation of a drop in voltage and correction of a current waveform.

Preferably, the electromagnetic interference analysis method as defined in any one of claims 15 through 23, wherein the calculation step includes a step of modeling the amount of instantaneous electric current while separating the same into a short circuit electric current component and a charge current component.

Preferably, the modeling step includes

a triangular waveform modeling step of modeling the instantaneous current as a triangular waveform whose width is calculated for each event information in consideration of slew information (i.e., an output slew) for an output terminal of a cell for each event information such that the area of the triangular waveform becomes equal to the amount of electric current of each event, the height of the triangular waveform being calculated on the basis of the width, and

the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the triangular waveform modeling step.

Preferably, the modeling step includes

a triangular height calculation step of calculating the height of a triangular waveform such that the area of the triangular waveform becomes equal to the amount of electric current of each event, by means of multiplying the amount of instantaneous electric current by a coefficient corresponding to the state of an event of a cell, in consideration of whether the event of the cell is in a rising state or a falling state.

Preferably, the modeling step includes

a step of calculating the amount of instantaneous

electric current for each event information in the case of a composite cell; and

a triangular waveform modeling step of modeling the amount of instantaneous electric current as a plurality of triangular waveforms which are equal in number to the stages provided in the composite cell, through use of a table representing the relationship between the width and height of a triangular waveform; and

the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the triangular waveform modeling step.

Further, the present invention provides an electromagnetic interference analysis system for analyzing the amount of electromagnetic interference arising in an LSI by means of performing a logic simulation, the system comprising:

a logic simulator;

computation means which is connected to the logic simulator and calculates the amount of instantaneous electric current from event information, the information being produced when a change arises in a signal and including the instance name of each cell in which the change has arisen, the name of the signal, a time at which the change has arisen, and transition information;

modeling means for modeling the instantaneous electric current according to a predetermined rule; and

fast Fourier (FFT) conversion means for subjecting to fast Fourier processing the information concerning a change in electric current, the information being calculated through a modeling step , thereby analyzing the amount of electromagnetic interference arising in an LSI on the basis of a signal output from the FFT conversion means.

Brief Description of the Drawings

FIG. 1 is a block diagram showing the overall flow of processing pertaining to an EMI analysis method according to a first embodiment of the present invention;

FIG. 2 is a block diagram showing a current waveform calculation section according to the first embodiment;

FIG. 3 is a graph showing a calculation result of an instantaneous current;

FIG. 4 is a flowchart showing processing for averaging a current waveform;

FIG. 5 is a graph showing a calculation result of a current waveform (according to the first embodiment);

FIG. 6 is a graph showing a result of an FFT operation;

FIG. 7 shows a rectangular waveform model (according

to a second embodiment of the present invention);

FIG. 8 is a block diagram showing calculation of a current waveform (according to the second embodiment);

FIG. 9 is a flowchart showing a first rectangular waveform-shaping operation;

FIG. 10 is a graph showing a calculation result of a current waveform (according to the second embodiment);

FIG. 11 shows a rectangular waveform model (according to a third embodiment of the present invention);

FIG. 12 is a block diagram showing calculation of a current waveform (according to the third embodiment);

FIG. 13 is a flowchart showing a second rectangular waveform-shaping operation;

FIG. 14 is a graph showing a calculation result of a current waveform (according to the third embodiment);

FIG. 15 shows a rectangular waveform model (according to fourth, fifth, and sixth embodiments of the present invention);

FIG. 16 shows an i-h table;

FIG. 17 is a block diagram showing calculation of a current waveform (according to a fourth embodiment of the present invention);

FIG. 18 is a flowchart showing a third rectangular waveform-shaping operation;

FIG. 19 is a graph showing a calculation result of a current waveform (according to the fourth embodiment);

FIG. 20 shows an i-s-h table;

FIG. 21 is a block diagram showing calculation of a current waveform (according to a fifth embodiment of the present invention);

FIG. 22 is a flowchart showing a fourth rectangular waveform-shaping operation;

FIG. 23 is a graph showing a calculation result of a current waveform (according to the fifth embodiment);

FIG. 24 shows an i-c-h table;

FIG. 25 is a block diagram showing calculation of a current waveform (according to a sixth embodiment of the present invention);

FIG. 26 is a flowchart showing a fifth rectangular waveform-shaping operation;

FIG. 27 is a graph showing a calculation result of a current waveform (according to the sixth embodiment);

FIG. 28 is a flowchart for describing an EMI analysis method according to a seventh embodiment of the present invention;

FIG. 29 is a flowchart for describing the flow of processing operations of a line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 30 is a schematic representation showing layout data which are entered into the line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 31 is a schematic representation showing information about segments in a power line, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 32 is a schematic representation showing information about the resistance of each of segments, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 33 is a schematic representation showing information about an electric current flowing in each of segments, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 34 is a schematic representation showing information about a drop in the voltage of each of segments, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 35 is a schematic representation showing

information about a drop in the voltage of each instance, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the seventh embodiment;

FIG. 36 is a flowchart for describing an EMI analysis method according to an eighth embodiment of the present invention;

FIG. 37 is a flowchart for describing the flow of processing operations of a line voltage drop calculation/instantaneous current correction section according to the eighth embodiment;

FIG. 38 is a schematic representation showing information about a capacitor provided between segments, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the eighth embodiment;

FIG. 39 is a schematic representation showing information about a drop in voltage of each of segments, which information is produced in the line voltage drop calculation/instantaneous current correction section according to the eighth embodiment;

FIG. 40 is a flowchart for describing an EMI analysis method according to a ninth embodiment of the present invention;

FIG. 41 a flowchart for describing the flow of

processing operations of a line voltage drop calculation/instantaneous current correction section according to a ninth embodiment of the present invention;

FIG. 42 shows a triangular waveform model (according to a tenth embodiment of the present invention);

FIG. 43 is a block diagram showing a current waveform calculation section (according to a tenth embodiment of the present invention);

FIG. 44 is a flowchart of a triangular waveform-shaping operation (according to the tenth embodiment);

FIG. 45 is a graph showing a calculation result of a current waveform (according to the tenth embodiment);

FIG. 46 is a multi-order-function model (according to an eleventh embodiment of the present invention);

FIG. 47 is a block diagram showing a current waveform calculation section (according to a tenth embodiment of the present invention);

FIG. 48 is a flowchart of a multi-order-function waveform-shaping operation;

FIG. 49 is a graph showing a calculation result of a current waveform (according to an eleventh embodiment of the present invention);

FIG. 50 is a schematic representation showing a Gaussian model (according to twelfth and twenty-fifth embodiments of the present invention);

FIG. 51 is an i-h table;

FIG. 52 is an i-w table;

FIG. 53 is a block diagram showing a current waveform calculation section (according to a twelfth embodiment of the present invention);

FIG. 54 is a flowchart of a Gaussian function waveform-shaping operation;

FIG. 55 is a graph showing a calculation result of a current waveform (according to a twelfth embodiment of the present invention);

FIG. 56 is a block diagram showing the configuration of a system for effecting an EMI analysis method according to a thirteenth embodiment of the present invention;

FIG. 57 is an illustration showing example data stored in means for storing basic information to be used for estimating an electric current according to the thirteenth embodiment;

FIG. 58 is a graph showing example data stored in total current storage means according to the thirteenth embodiment;

FIG. 59 is a graph showing example data stored in element current storage means according to the thirteenth embodiment;

FIG. 60 is a flowchart showing processing operations of the total current calculation means according to the

thirteenth embodiment;

FIG. 61 is a block diagram showing a current waveform calculation section (according to a fourteenth embodiment of the present invention);

FIG. 62 is a flowchart of a sixth rectangular waveform-shaping operation;

FIG. 63 shows an s-h table;

FIG. 64 is a block diagram showing a current waveform calculation section (according to a fifteenth embodiment of the present invention);

FIG. 65 is a flowchart of a seventh rectangular waveform-shaping operation;

FIG. 66 shows a c-h table;

FIG. 67 is a block diagram showing a current waveform calculation section (according to a sixteenth embodiment of the present invention);

FIG. 68 is a flowchart of an eighth rectangular waveform-shaping operation;

FIG. 69 is a graph showing example data stored in a pattern-of-signal-change storage means according to the seventeenthembodimentof the present invention;

FIG. 70 is a graph showing an example current waveform arising in a real circuit according to the seventeenth embodiment;

FIG. 71 is a graph showing example data stored in

conventional total current storage means according to the thirteenth embodiment;

FIG. 72 is a block diagram showing the configuration of a system for effecting a gate-level EMI analysis method according to the seventeenth embodiment and an eighteenth embodiment of the present invention;

FIG. 73 is an illustration showing example data stored in circuit connection information storage means according to the seventeenth embodiment;

FIG. 74 is a graph showing example data stored in total current storage means according to the seventeenth embodiment;

FIG. 75 is a graph showing example data stored in element current storage means according to the seventeenth embodiment;

FIG. 76 is a flowchart showing processing operations of the total current calculation means according to the seventeenth embodiment;

FIG. 77 is an illustration showing example data stored in circuit connection information storage means according to the eighteenth embodiment;

FIG. 78 is a graph showing example data stored in a pattern-of-signal-change storage means according to the eighteenth embodiment;

FIG. 79 is a graph showing an example current

waveform arising in a real circuit according to the eighteenth embodiment;

FIG. 80 is a graph showing example data stored in conventional total current storage means according to the eighteenth embodiment;

FIG. 81 is a graph showing example data stored in element current storage means according to the eighteenth embodiment;

FIG. 82 is a graph showing example data stored in total current storage means according to the eighteenth embodiment;

FIG. 83 is a flowchart showing processing operations of the total current calculation means according to the eighteenth embodiment;

FIG. 84 is an illustration showing example data stored in circuit connection information storage means according to a nineteenth embodiment of the present invention;

FIG. 85 is a graph showing example data stored in a pattern-of-signal-change storage means according to the nineteenth embodiment;

FIG. 86 is a graph showing an example current waveform arising in a real circuit according to the nineteenth embodiment;

FIG. 87 is a graph showing example data stored in

conventional total current storage means according to the nineteenth embodiment;

FIG. 88 is a graph showing example data stored in element current storage means according to the nineteenth embodiment;

FIG. 89 is a flowchart showing processing operations of the total current calculation means according to the nineteenth embodiment;

FIG. 90 is a graph showing example data stored in total current storage means according to the nineteenth embodiment;

FIG. 91 is a flowchart for describing an EMI analysis method according to a twentieth embodiment of the present invention;

FIG. 92 is a flowchart for describing the flow of processing operations of a line voltage drop calculation/instantaneous current correction section according to the twentieth embodiment;

FIG. 93 is a flowchart for describing an EMI analysis method according to a twenty-first embodiment of the present invention;

FIG. 94 is a flowchart for describing the flow of processing operations of a line voltage drop calculation/instantaneous current correction section according to the twenty-first embodiment;

FIG. 95 is a flowchart for describing an EMI analysis method according to a twenty-second embodiment of the present invention;

FIG. 96 shows a triangular waveform model (according to a twenty-third embodiment of the present invention);

FIG. 97 is a block diagram showing a current waveform calculation section (according to the twenty-third);

FIG. 98 is a flowchart of a triangular waveform-shaping operation;

FIG. 99 is a multi-order-function model (according to a twenty-fourth embodiment of the present invention);

FIG. 100 is a block diagram showing a current waveform calculation section (according to the twenty-fourth embodiment);

FIG. 101 is a flowchart of a multi-order-function waveform-shaping operation;

FIG. 102 is a block diagram showing a current waveform calculation section (according to a twenty-fifth embodiment of the present invention);

FIG. 103 is a flowchart of a Gaussian function waveform-shaping operation;

FIG. 104 is a graph showing an example current waveform arising in a real circuit according to a twenty-sixth embodiment of the present invention;

FIG. 105 is a graph showing example data stored in

element current storage means according to the twenty-sixth embodiment;

FIG. 106 is a graph showing example data stored in conventional total current storage means according to the twenty-sixth embodiment;

FIG. 107 is a flowchart showing processing operations of the total current calculation means according to the twenty-sixth embodiment;

FIG. 108 is a diagram showing example data concerning internal connections stored in the circuit connection information storage means according to the seventeenth embodiment shown in FIG. 73;

FIG. 109 is a block diagram showing the configuration of a system for effecting an EMI analysis method employed in an example conventional EMI analysis method;

FIG. 110 is an illustration showing example data stored in circuit connection information storage means employed in an example conventional EMI analysis method and in a twenty-sixth embodiment;

FIG. 111 is a graph showing example data stored in a pattern-of-signal-change storage means employed in an example conventional EMI analysis method and in the twenty-sixth embodiment;

FIG. 112 is a graph showing example data stored in element current storage means employed in an example

conventional EMI analysis method;

FIG. 113 is a graph showing example data stored in total current storage means employed in an example conventional EMI analysis method;

FIG. 114 is a flowchart showing processing operations of the total current calculation means employed in an example conventional EMI analysis method;

FIG. 115 is a diagram of changes in signals flowing through an internal net of a circuit, the changes being detected according to an example conventional EMI analysis method;

FIG. 116 is a flowchart for describing an example conventional EMI analysis method;

FIG. 117 is a triangular waveform model according to the present invention (a twenty-seventh embodiment);

FIG. 118 is a block diagram showing calculation of a current waveform (according to the twenty-seventh embodiment);

FIG. 119 is a flowchart showing shaping of a triangular waveform (according to the twenty-seventh embodiment);

FIG. 120 shows a triangular waveform model according to the present invention (a twenty-eighth embodiment);

FIG. 121 is a block diagram showing calculation of a current waveform (according to the twenty-eighth

embodiment);

FIG. 122 shows a triangular waveform model according to the present invention (a twenty-ninth embodiment); and

FIG. 123 is a block diagram showing calculation of a current waveform (according to the twenty-ninth embodiment).

Description of the preferred Embodiments(First Embodiment)

An electromagnetic interference (EMI) analysis method according to a first embodiment of the present invention will be described hereinbelow. The EMI analysis method is characterized by calculating a current waveform.

The method comprises the steps of:

extracting event information on a per-cell basis from a logic simulator;

calculating from the event information a momentarily-changing current of each cell;

averaging the instantaneously-changing current by means of dividing by a certain duration of time, to thereby calculate a more realistic change in current; and

subjecting the calculation result of a current waveform to fast Fourier transformation (FFT), to thereby determine a frequency characteristic of electromagnetic

interference (EMI) emitted from a circuit of interest, to thereby effect EMI analysis.

FIG. 1 is a block diagram showing the overall flow of processing pertaining to the EMI analysis method of the first embodiment. In the drawing, there are described a netlist 1 representing data pertaining to a circuit to be subjected to EMI analysis; a test vector 2 for activating the netlist 1; a library 3 having described therein information concerning individual cells constituting the netlist 1; a logic simulator 4 for performing a simulation on the basis of the information from the library 3; and a current waveform calculation section 7 for calculating a current waveform from event information 5, the information having been calculated on a per-cell basis by means of the logic simulator 4. An FFT processing section 9 performs an FFT processing operation on the basis of a current waveform calculation result 8 calculated by the current waveform calculation section 7, to thereby calculate an EMI component. Accordingly, there is obtained an EMI analysis result 10 of the circuit of interest. Thus, the EMI analysis method is characterized by use of the current waveform calculation section 7. The logic of a cell, delay information concerning the cell, and momentary-current-value information concerning the cell are described in the library 3 according to the types

of individual cells. Every time an event arises, the logic simulator 4 outputs the event information 5. The term "event" used herein designates occurrence of any change in a signal within the logic simulator 4. The event information 5 contains the instance name of an object of EMI analysis which accounts for outputting of the event information 5, the name of a signal in which change has arisen, the time at which the change has arisen, and information concerning transition of the signal. The expression "instance name" corresponds to a proper name assigned to each of the cells constituting the netlist 1. Reference numeral 6 designates a simulation result output from the logic simulator 4.

As can be seen from a detail block diagram shown in FIG. 2, the current waveform calculation section 7 comprises an instantaneously-changing current calculation section 11 and calculates an instantaneously-changing current from information concerning an instantaneously-changing current of an instance calculated by the instantaneously-changing current calculation section 11, the instance serving as an object of EMI analysis. On the basis of a calculation result 12 of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12"), the current waveform

calculation section 7 averages a current waveform by means of dividing an instantaneously-changing current by a predetermined duration of time. The instantaneously-changing current calculation section 11 calculates a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Upon receipt of the event information 5 output from the logic simulator 4, the instantaneously-changing current calculation section 11 extracts, from the library 3, information concerning an instantaneously-changing current of an instance, the instance being an object of EMI analysis, to thereby calculate an instantaneously-changing current.

Reference numeral 12 designates an instantaneously-changing current calculation result determined by the instantaneously-changing current calculation section 11. FIG. 3 is a plot showing an example instantaneously-changing current calculation result 12. In the drawing, the vertical axis represents the amount of current "it" (As), and the horizontal axis represents time "t." Reference symbol T designates a duration of time for averaging a current waveform by means of dividing an

instantaneously-changing current by a certain duration of time and corresponds to a predetermined constant. Δt designates a minimum time unit to be used for analysis and differs from the minimum unit time of the logic simulator 4. Reference symbol "t" denotes a current processing time and corresponds to a simulation time of the logic simulator 4. Reference symbol "it" denotes the value of an instantaneously-changing current. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. In order to enable analysis of an EMI component through FFT, a current waveform averaging section 13 averages the instantaneously-changing current calculation result 12 by means of dividing by a certain duration of time.

FIG. 4 shows a flowchart of steps relating to averaging of a current waveform. The following processing operations are repeated until an averaging operation is completed; namely, until "t" exceeds an end time of simulation (step 1010). First, a current buffer "Ib" for averaging purpose is set to 0 (step 1011). Next, i(t) is added to "Ib" until the current time "t" becomes "t+T" (steps 1012 and 1013). Here, i(t) denotes an instantaneously-changing current at time "t" (step 1014).

Next, I_{ave} is assigned to I(x) until a variable "x" shifts from -T to "t," thereby adding Δt to the variable "x" (steps 1015 and 1016). Here, I(x) denotes a current at time "x."

The current waveform calculation result 8 can be determined by means of the flowchart of averaging operations. FIG. 5 shows a current waveform calculation result 8 obtained at time T=5 provided in the instantaneously-changing current calculation result 8 shown in FIG. 3. The FFT processing section 9 subjects the thus-calculated waveform to an FFT processing operation, thereby determining the frequency characteristic of an EMI component. In this way, there can be obtained a result 10 of EMI analysis (hereinafter referred to as an "EMI analysis result 10"). FIG. 6 shows a sample of the EMI analysis result 10. From the EMI analysis result 10, the frequency characteristic of an EMI component arising in the circuit of interest can be determined, and the designer of the circuit can study a method of addressing EMI.

The EMI analysis method of the present embodiment models a current waveform by means of an averaging operation and subjecting the thus-modeled waveform to an FFT operation, to thereby enable highly-precise analysis of EMI. Further, the EMI analysis method of the present embodiment can analyze an EMI component of a circuit within

a shorter period of time than can a transistor-level EMI analysis method.

(Second Embodiment)

An electromagnetic interference (EMI) analysis method according to a second embodiment of the present invention will be described hereinbelow. The EMI analysis method comprises the steps of:

calculating a momentarily-changing current of each cell from the event information 5 output from the logic simulator 4;

modeling the thus-calculated momentarily-changing current a rectangular waveform having a certain duration of time, the peak value of the waveform having been calculated such that an instantaneously-changing current coincides with the area of the rectangular waveform. Accordingly, a more realistic change in current is calculated, and the calculation result of a current waveform is subjected to FFT operation, wherewith a frequency characteristic of an EMI component arising in a circuit of interest is determined and EMI analysis is effected.

FIG. 7 shows an instantaneously-changing current value and a modeled rectangular waveform according to the second embodiment. In the drawing, "i" represents an instantaneously-changing current value, and "t" denotes

a current processing time. Reference symbol "W" denotes the width of a modeled rectangular waveform. The width of a rectangular waveforms corresponds to a predetermined constant. Further, reference symbol "h" denotes the height of a rectangular waveform, which is to be calculated from "i" and "W."

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 8 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example

instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with that of the current wave calculation operation of the first embodiment. The EMI analysis method according to the present embodiment comprises a first rectangular waveform height calculation section 20 for calculating the height of a rectangular waveform such that the area of a rectangular waveform serving as a model of the waveform of the instantaneously-changing current coincides with the instantaneously-changing current value; and a first rectangular waveform-shaping section 21 for modeling the instantaneously-changing current calculation result 12 as a rectangular waveform having a certain duration of time, thereby calculating the waveform of an electric current.

FIG. 9 shows a flow of rectangular waveform-shaping operations including an operation for calculating the height of a rectangular waveform. The following operation is repeated on a per-event basis until a current wave calculation operation is completed (step 1020). The area of a rectangular waveform is defined as "W x h" and

assumes a value of "i." The height "h" of the rectangular waveform is calculated as i/W (step 1021). Symbol "i" denotes an instantaneously-changing current value concerning a cell of an event, the event being an object of EMI analysis. This processing corresponds to processing pertaining to the first rectangular waveform height calculation section 20. Next, "h" is added to I(t+x) until a variable "x" changes from -W/2 to W/2, and Δt is added to "x" (steps 1022 and 1023). I(t+x) corresponds to the value of electric current flowing through all the cells at time t+x. This processing corresponds to processing pertaining to the first rectangular waveform-shaping section 21.

The current wave calculation result 8 can be obtained by means of the flow of a rectangular waveform height calculation operation and a rectangular waveform-shaping operation. FIG. 10 shows an example current wave calculation result 8 at W=5 in the instantaneously-changing current calculation result shown in FIG. 3. The FFT processing section 9 subjects the waveform to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

According to the EMI analysis method of the present embodiment, the waveform of a current is modeled as a

rectangular waveform, and the thus-modeled rectangular waveform is subjected to an FFT operation, thereby enabling more accurate analysis of EMI. The EMI analysis method according to the present embodiment enables processing within a more shorter period of time than does the transistor-level EMI analysis method.

(Third Embodiment)

An EMI analysis method according to a third embodiment of the present invention will now be described. Under the EMI analysis method according to the present embodiment, a momentarily-changing current of each cell is calculated from event information concerning to each cell, the information being output from a logic simulator. The momentarily-changing current is modeled as a rectangular waveform, wherein a ratio of a duration of time to a peak value is made constant such that an instantaneously-changing current value becomes equal to the area of the rectangular waveform. As a result, there is calculated a more realistic change in current, and the result of calculation of a current waveform is subjected to an FFT operation, to thereby determine the frequency characteristic of an EMI component of a circuit of interest and enable EMI analysis. The EMI analysis method will now be described.

FIG. 11 shows a momentary current value and a modeled

rectangular waveform according to the third embodiment. Reference symbol "i" denotes an instantaneously-changing current value, and "t" denotes a current processing time. Reference symbol "K" denotes a ratio of a peak value of a rectangular waveform to a duration of time. In the present embodiment, the ratio is expressed as "peak-value/width." The peak-value/width ratio is constant, and an appropriate value has been determined beforehand as the value of the peak-value/width ratio. Reference symbol "h" denotes the height of a rectangular waveform, and the height "h" is determined from the value of "i" and the value of "K." Further, reference symbol "w" denotes the width of a rectangular waveform, and the width "w" of a rectangular waveform is calculated from the value of "h," which has been calculated previously, and the value of "i."

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 12 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the

information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, processing has been identical with the current wave calculation operation of the first embodiment.

Reference numeral 30 designates a second rectangular waveform height calculation section for calculating the height of a rectangular waveform such that a ratio of a peak value of a rectangular waveform to be modeled to a duration of time is constant and such that the area of a rectangular waveform becomes equal to an instantaneously-changing current value. Reference numeral 31 designates a second rectangular waveform width

calculation section for calculating the width of a rectangular waveform such that a ratio of a peak value of a rectangular waveform serving as a model of the waveform of the instantaneously-changing current to a duration of time is constant and such that the area of a rectangular waveform becomes equal to an instantaneously-changing current value. Reference numeral 32 designates a second rectangular waveform-shaping section for modeling the instantaneously-changing current calculation result 12 as a rectangular waveform having a constant peak-value/width ratio.

FIG. 13 shows the flowchart of processing pertaining to the second rectangular waveform-shaping section, including processing pertaining to the second rectangular waveform height calculation section and processing pertaining to the second rectangular waveform width calculation section. The following processing is iterated on a per-event basis until calculation of a current waveform is completed (step 1030). The height of a rectangular waveform is expressed by Eq. 1 provided below, from the area of a rectangular waveform and "K = h/w."

$$h = \sqrt{(i \times K)} \quad \text{... (1)}$$

The height "h" of a rectangular waveform is calculated through use of Eq.1 (step 1031). Reference symbol "i" denotes the value of an instantaneously-changing current

of a cell of an event, the event being an object of EMI analysis. Reference symbol "K" denotes a ratio of a peak value of a rectangular waveform to the width of the same and assumes a predetermined constant. This processing corresponds to processing pertaining to the second rectangular waveform height calculation section 30. The area of a rectangular waveform is defined by "w x h." The width "w" of a rectangular waveform is calculated on the basis of "w = i/h" (1032). Reference symbol "h" denotes the height "h" of a rectangular waveform calculated through processing pertaining to step 1031. This processing corresponds to processing pertaining to the second rectangular waveform width calculation section 31. Next, "h" is added to I(t+x) until a variable "x" changes from -W/2 to W/2, and Δt is added to "x" (steps 1033 and 1034). I(t+x) corresponds to the value of electric current flowing through all the cells at time t+x. This processing corresponds to processing pertaining to the second rectangular waveform-shaping section 32.

The current wave calculation result 8 can be obtained by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. FIG. 14 shows an example current wave calculation result 8 in the instantaneously-changing

current calculation result shown in FIG. 3. The FFT processing section 9 subjects the waveform to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

According to the EMI analysis method of the present embodiment, the waveform of a current is modeled as a rectangular waveform having a constant peak-value/width ratio, and the thus-modeled rectangular waveform is subjected to an FFT operation, thereby enabling more accurate analysis of EMI. In an LSI circuit involving flow of a large amount of electric current, flow of an electric current consumes a long time. The EMI analysis method according to the present embodiment enables realization of a more realistic model and hence enables more accurate processing. Further, the EMI analysis method enables EMI analysis within a much shorter period of time than the transistor-level EMI analysis method.

(Fourth Embodiment)

A fourth embodiment of the present invention will now be described. The present embodiment describes a method of analyzing EMI by the steps of:

calculating an instantaneously-changing current of each current from event information concerning each cell, the information being output from a logic simulator;

modeling the instantaneously-changing current as a rectangular waveform whose area becomes equal to the instantaneously-changing current, through use of a global table representing the relationship between an instantaneously-changing current and the height of a rectangular waveform, to thereby calculate a more realistic change in current; and

subjecting a calculation result of the current waveform to an FFT operation, to thereby determine the frequency characteristic of an EMI component of a circuit of interest. The global table signifies a table which is generally prepared without regard to the type of a cell.

FIG. 15 shows an instantaneously-changing current value and a modeled rectangular waveform according to the present embodiment. Reference symbol "i" denotes an instantaneously-changing current; "t" denotes a current processing time; and "h" denotes the height of a rectangular waveform serving as a model of the waveform of the instantaneously-changing current. The height of a rectangular waveform is calculated, through use of a global table representing the relationship between an instantaneously-changing current value and the height of a rectangular waveform. Reference symbol "w" denotes the width of a rectangular waveform, and the width "w" of a rectangular waveform is calculated from the value of "h,"

which has been calculated previously, and the value of "i."

FIG. 16 is a graph showing an example global i-h table representing the relationship between an instantaneously-changing current value and the height of a rectangular waveform. The table shows the value of "h" at each of certain points "i." The table indicates that "h" assumes a value of 0 at i=0, a value of 5 at i=50, and a value of 20 at i=100. In reality, the value of "i" changes continuously, and hence the table is expressed as a graph plotting points provided in the table. The value of "h" [i.e., h(i)] at a certain value of "i" is expressed by Eq.2 provided below, through linear interpolation of the values of two points closest to "i" provided in the i-h table: one point has lower values (i1, h1), and the other point has higher values (i2, h2).

$$h = \frac{h2 - h1}{i2 - i1}(i - i1) + h1 \quad \ldots \quad (2)$$

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 17 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for

calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment.

In the present embodiment, an i-h table 40 has described therein the previously-described global table representing the relationship between an instantaneously-changing current value and the height of a rectangular waveform (see FIG. 16). A third rectangular waveform height calculation section 41 calculates a peak

value of a rectangular waveform serving as a model of an instantaneously-changing current, from an instantaneously-changing current value and the i-h table 40. A third rectangular waveform width calculation section 42 calculates the width of a rectangular waveform from a peak value of a rectangular waveform calculated by the third rectangular waveform height calculation section 41, and the instantaneously-changing current value. A third rectangular waveform-shaping section 43 models the instantaneously-changing current calculation result 12 as a rectangular waveform, the height of the rectangular waveform corresponding to the peak value of the rectangular waveform calculated by the third rectangular waveform height calculation section 41, and the width of the rectangular waveform corresponding to the width calculated by the third rectangular waveform width calculation section 42.

FIG. 18 is a flowchart showing processing pertaining to the third rectangular waveform-shaping section 43, including processing pertaining to the rectangular waveform height calculation section 41 and processing pertaining to the rectangular waveform width calculation section 42. First, the i-h table 40 is read (step 1040). Next, the subsequent processing operations are iterated on a per-event basis until the current waveform

calculation operation is completed (step 1041). Two points closest to "i," (i1, h1) and (i2, h2), are extracted from the i-h table 40. Reference symbol "i" is the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. In the table shown in FIG. 16, the two points closest to i=70 are (i1, h1) = (50, 5) and (i2, h2) = (100, 20) (step 1042).

The height "h" of a rectangular waveform is calculated according to Eq.2 (step 1043). In connection with the table shown in FIG. 16, in the case where i=70, h(70)=11. This processing; i.e., processing pertaining to steps 1042 and 1043, corresponds to processing pertaining to the third rectangular waveform height calculation section 41. The area of a rectangular waveform is defined as "w x h." The width "w" of a rectangular waveform is calculated from w=i/h (step 1044). Reference symbol "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. Reference symbol "h" denotes the height of a rectangular waveform calculated by the third rectangular waveform height calculation section 41. In the table shown in FIG. 16, when i=70, w=6.3. This processing corresponds to processing pertaining to the third rectangular waveform width calculation section 42. Next, "h" is added to I(t+x)

until variable "x" changes from -W/2 to W/2, and Δt is added to variable "x" (steps 1045 and 1046). I(t+x) denotes electric currents flowing through all the cells at time "t+x." This processing corresponds to processing pertaining to the third rectangular waveform-shaping section 43.

The current waveform calculation result 8 can be determined by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. FIG. 19 shows an example current waveform calculation result 8 obtained in a case where the table shown in FIG. 16 is used as the i-h table 40 and where the instantaneously-changing current value is 70. The rectangular waveform shown in FIG. 19 is subjected to an FFT operation by the FFT processing section 9, to thereby determine the frequency characteristic of an EMI component. Thus, there can be obtained an EMI analysis result 10.

(Fifth Embodiment)

An EMI analysis method according to a fifth embodiment of the present invention will now be described. The present embodiment describes the EMI analysis method comprising the steps of:

calculating an instantaneously-changing current of

each cell from event information concerning each cell, the event information being output from a logic simulator;

modeling the instantaneously-changing current into a rectangular waveform whose area becomes equal to the instantaneously-changing current, through use of a global table representing the relationship among a slew in an input waveform, an instantaneously-changing current value, and the height of a rectangular waveform, to thereby calculate a change in current in consideration of the more-realistic slew in an input waveform; and

subjecting the result of calculation of the current waveform to an FFT operation, thereby determining the frequency characteristic of an EMI component arising in a circuit of interest.

The relationship between the instantaneously-changing current value and a modeled rectangular waveform according to the present embodiment is the same as in the case of the rectangular waveform model according to the fourth embodiment (shown in FIG. 15), except that "w" and "h" are calculated in consideration of the influence of slew in an input waveform. FIG. 20 shows an example global i-s-h table representing the relationship among an instantaneously-changing current value, the slew in an input waveform, and the height of a rectangular waveform, and a graph plotting the i-s-h table. The table shows the

value of "h" at a certain point (i, s), where "s" denotes the slew (or slew) of an input waveform. In connection with this table, "h" assumes a value of 0 at i=0 and s=0; a value of 5 at i=50 and s=0; a value of 14 at i=100 and s=0; a value of 0 at i=0 and s=2; a value of 6 at i=50 and s=2; and a value of 20 at i=100 and s=2. In reality, the value of "i" and the value of "s" change continuously, and hence the table is represented by a three-dimensional graph plotting points appearing in the table. The value of h(s,i) at a certain value of "s" and a certain value of "i" is expressed by Eq.3 provided below, through use of four points in combination, the four points comprising a combination of a low value (i1) and a high value (i2) closest to "i" within the i-s-h table and a low value (s1) and a high value (s2) closest to "s"; namely, h(s1, i1), h(s1, i2), h(s2, i1), and h(s2, i2).

$$h(s,i)=\left[\frac{h(s1,i1)(s2-s)}{(s2-s1)}+\frac{h(s2,i1)(s-s1)}{(s2-s1)}\right]\left(\frac{i2-i}{i2-i1}\right)+\left[\frac{h(s1,i2)(s2-s)}{(s2-s1)}+\frac{h(s2,i2)(s-s1)}{(s2-s1)}\right]\left(\frac{i-i1}{i2-i1}\right)$$

... (3)

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 21 is a detailed block diagram showing the current waveform calculation section 7 according to the

present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment.

The i-s-h table 50 employed in the present embodiment is the above-described global table representing the relationship among an instantaneously-changing current value, the slew in an input waveform, and the height of

a rectangular waveform (FIG. 20). A fourth rectangular waveform height calculation section 52 calculates a peak value of a rectangular waveform serving as a model of an instantaneously-changing current, from an instantaneously-changing current value of an instance serving as an object of EMI analysis, the slew in an input waveform, and the i-s-h table 50, all of which are read from Slew data 51. The Slew data 51 are provided in the netlist 1 and describe information concerning the slew in a waveform input to each instance. Reference numeral 53 designates a fourth rectangular waveform width calculation section for calculating the width of a rectangular waveform, through use of the peak value calculated by the fourth rectangular waveform height calculation section 52 and the instantaneously-changing current value such that the area of the rectangular waveform becomes equal to the instantaneously-changing current value. Reference numeral 54 designates a fourth rectangular waveform-shaping section for modeling the instantaneously-changing current calculation result 12 as a rectangular waveform, the height of the rectangular waveform corresponding to the peak value calculated by the fourth rectangular waveform height calculation section 52, and the width of the rectangular waveform corresponding to the width calculated by the fourth rectangular waveform

width calculation section 53.

FIG. 22 shows the flowchart of processing pertaining to the fourth rectangular waveform-shaping section 54, including processing pertaining to the rectangular waveform height calculation section 52 and processing pertaining to the rectangular waveform width calculation section 53. First, the i-s-h table 50 is read (step 1050), and the Slew data 51 are read (step 1051). The processing provided below is iterated on a per-event basis until calculation of a current waveform is completed (step 1052). From the i-s-h table 50, there are extracted four points which are combinations of a low value closest to "i," a high value closest to "i," a low value closest to "s," and a high value closest to "s"; for example, h(s1, i1), h(s1, i2), h(s2, i1), and h(s2, i2). Here, reference symbol "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. Further, reference symbol "s" denotes the slew in an input waveform pertaining to the cell. The four points are extracted on the basis of the name of the instance to be processed and the Slew data 51.

In connection with the table shown in FIG. 20, in the case of i=70 and s=1, there are extracted four values; h(0, 50)=5, h(0, 100)=14, h(2, 50)=6, and h(2, 100)=20

(step 1053). The height "h" of the rectangular waveform is calculated by Eq.3 (step 1054). In connection with the table shown in FIG. 20, in the case where i=70 and s=1, h(1, 70)=10.1. Processing pertaining to steps 1053 and 1054 correspond to processing pertaining to the fourth rectangular waveform height calculation section 52.

The area of the rectangular waveform is defined by "w x h." The duration (w) of a rectangular waveform is calculated on the basis of w=i/h (step 1055). Here, "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis, and "h" denotes the height of a rectangular waveform calculated by the fourth rectangular waveform height calculation section 52.

In connection with the table shown in FIG. 20, in the case of i=70 and s=1, w=6.9. This processing corresponds to processing pertaining to the fourth rectangular waveform width calculation section 53. Next, "h" is added to I(t+x) until variable "x" changes from -W/2 to W/2, and Δt is added to "x" (steps 1056 and 1057). Here, I(t+x) represents total current flowing through all the cells at time "t+x." This processing corresponds to processing pertaining to the fourth rectangular waveform-shaping section 54.

The current waveform calculation result 8 can be determined by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. FIG. 23 shows an example current waveform calculation result 8 obtained in a case where the i-s-h table 50 corresponds to the table shown in FIG. 20, the instantaneously-changing current value is 70, and the slew in an input waveform assumes a value of 1. The rectangular waveform is subjected to an FFT operation by the FFT processing section 9, to thereby determine the frequency characteristic of an EMI component. Thus, there can be obtained an EMI analysis result 10.

(Sixth Embodiment)

An EMI analysis method according to a sixth embodiment of the present invention will now be described. The present embodiment describes the EMI analysis method comprising the steps of:

calculating an instantaneously-changing current of each cell from event information concerning each cell, the event information being output from a logic simulator;

modeling the instantaneously-changing current as a rectangular waveform whose area becomes equal to the instantaneously-changing current, through use of a global table representing the relationship among an output load

capacitance, an instantaneously-changing current value, and the height of a rectangular waveform, to thereby calculate a change in current in consideration of the more-realistic output load capacitance; and

subjecting the result of calculation of the current waveform to an FFT operation, thereby determining the frequency characteristic of an EMI component arising in a circuit of interest.

The relationship between the instantaneously-changing current value and a modeled rectangular waveform according to the present embodiment is the same as in the case of the rectangular waveform model according to the fourth embodiment (shown in FIG. 15), except that "w" and "h" are calculated in consideration of the influence of slew in an input waveform. FIG. 24 shows an example global i-c-h table representing the relationship among an instantaneously-changing current value, an output load capacitance, and the height of a rectangular waveform, and a graph plotting the i-c-h table. The table shows the value of "h" at a certain point (i, c), where "c" denotes an output load capacitance. In connection with this table, "h" assumes a value of 0 at i=0 and c=0; a value of 5 at i=50 and c=0; a value of 20 at i=100 and c=0; a value of 0 at i=0 and c=20; a value of 8 at i=50 and c=20; and a value of 25 at i=100 and c=20. In reality, the value of

"i" and the value of "c" change continuously, and hence the table is represented by a three-dimensional graph plotting points appearing in the table. The value of h(c,i) at a certain value of "c" and a certain value of "i" is expressed by Eq.4 provided below, through use of four points in combination, the four points comprising a combination of a low value (i1) and a high value (i2) closest to "i" within the i-c-h table and a low value (c1) and a high value (c2) closest to "c"; namely, h(c1, i1), h(c1, i2), h(c2, i1), and h(c2, i2).

$$y = -\frac{2 \times h}{W} x + h \quad \ldots \quad (4)$$

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 25 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a

conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment.

The i-c-h table 60 employed in the present embodiment is the above-described global table representing the relationship between an instantaneously-changing current value and the height of a rectangular waveform (FIG. 24). Reference numeral 62 designates a fifth rectangular waveform height calculation section which calculates a peak value of a rectangular waveform serving as a model of an instantaneously-changing current, from an instantaneously-changing current value of an instance serving as an object of EMI analysis and an output load capacitance. Reference numeral 63 designates a fifth

rectangular waveform width calculation section for calculating the width of a rectangular waveform, through use of the peak value calculated by the fifth rectangular waveform height calculation section 62 and the instantaneously-changing current value and such that the area of the rectangular waveform becomes equal to the instantaneously-changing current value. Reference numeral 64 designates a fifth rectangular waveform-shaping section for modeling the instantaneously-changing current calculation result 12 as a rectangular waveform, the height of the rectangular waveform corresponding to the peak value calculated by the fifth rectangular waveform height calculation section 62, and the width of the rectangular waveform corresponding to the width calculated by the fifth rectangular waveform width calculation section 63.

FIG. 26 shows the flowchart of processing pertaining to the fifth rectangular waveform-shaping section 64, including processing pertaining to the rectangular waveform height calculation section 62 and processing pertaining to the rectangular waveform width calculation section 63. First, the i-c-h table 60 is read (step 1060), and capacitance data 61 are read (step 1061). The processing provided below is iterated on a per-event basis until calculation of a current waveform is completed (step

1062). From the i-c-h table 60, there are extracted four points which are combinations of a low value closest to "i," a high value closest to "i," a low value closest to "c," and a high value closest to "c"; for example, h(c1, i1), h(c1, i2), h(c2, i1), and h(c2, i2). Here, reference symbol "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. Further, reference symbol "c" denotes an output load capacitance pertaining to a cell of an event, the event being an object of EMI analysis. The four points are extracted on the basis of the name of instance to be processed and the capacitance data 61.

In connection with the table shown in FIG. 24, in the case where i=70 and c=10, there are extracted four values; h(0, 50)=5, h(0, 100)=20, h(20, 50)=8, and h(20, 100)=25 (step 1063). The height "h" of the rectangular waveform is calculated by Eq.3 (step 1064). In connection with the table shown in FIG. 24, in the case where i=70 and c=10, h(10, 70)=12.9. Processing pertaining to steps 1063 and 1064 corresponds to processing pertaining to the fifth rectangular waveform height calculation section 62. The area of the rectangular waveform is defined by "w x h." The duration (w) of a rectangular waveform is calculated on the basis of w=i/h (step 1065). Here, "i" denotes the value of an instantaneously-changing current

of a cell of an event, the event being an object of EMI analysis, and "h" denotes the height of a rectangular waveform calculated by the fifth rectangular waveform height calculation section 62.

In connection with the table shown in FIG. 24, in the case where i=70 and c=10, w=5.4. This processing corresponds to processing pertaining to the fifth rectangular waveform width calculation section 53. Next, "h" is added to I(t+x) until variable "x" changes from -W/2 to W/2, and Δt is added to "x" (steps 1066 and 1067). Here, I(t+x) represents total current flowing through all the cells at time "t+x." This processing corresponds to processing pertaining to the fifth rectangular waveform-shaping section 64.

The current waveform calculation result 8 can be determined by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. FIG. 27 shows an example current waveform calculation result 8 obtained in a case where the i-c-h table 60 corresponds to the table shown in FIG. 24, the instantaneously-changing current value is 70, and an output load capacitance assumes a value of 10. The rectangular waveform is subjected to an FFT operation by the FFT processing section 9, to thereby determine the

frequency characteristic of an EMI component. Thus, there can be obtained an EMI analysis result 10.

The EMI analysis method of the present embodiment forms a rectangular waveform model from a global table defining the relationship between an output load capacitance, an instantaneously-changing current value, and the height of a rectangular waveform, thereby enabling preparation of a more realistic model and more accurate processing.

(Seventh Embodiment)

An EMI analysis method according to a seventh embodiment of the present invention will now be described. FIG. 28 is a block diagram showing the overall flowchart of the EMI analysis method according to the present embodiment. The EMI analysis method according to the present embodiment is identical with the EMI analysis method according to the first embodiment described in connection with FIG. 1, except for addition of data A9 and A10, a voltage drop calculation/instantaneously-changing current correction section A11, and an instantaneously-changing current calculation result A6 output in step A11. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the first embodiment are assigned the same reference

numerals, and their repeated explanations are omitted. A9 designates data concerning the layout of a semiconductor integrated circuit which is an object of EMI analysis. A10 designates an I-V table file (or an I-V function) representing the relationship between the amount of electric current and the degree of a drop in line voltage. A11 designates a section of calculating a drop in line voltage and correcting the result of an instantaneously-changing current calculated in step 11 (hereinafter referred to as a "voltage drop calculation/instantaneously-changing current correction section"). A6 designates the result of an instantaneously-changing current being calculated by the voltage drop calculation/instantaneously-changing current correction section A11 in consideration of a drop in line voltage.

FIG. 29 is a block diagram showing the flow of processing of the voltage drop calculation/instantaneously-changing current correction section A11 according to the seventh embodiment of the present invention. The function of the voltage drop calculation/instantaneously-changing current correction section A11 will now be described by reference to FIG. 29. Since data 12 have already been described in detail in connection with the first embodiment, the same reference

numeral is assigned to the data 12, and repeated explanation is omitted. The voltage drop calculation/instantaneously-changing current correction section A11 comprises a power net extraction section B2, a section B6 for calculating the resistance of each segment (hereinafter referred to as a "segment resistance calculation section B6"), a section B3 for calculating an electric current flowing through each segment (hereinafter referred to as a "segment current calculation section B3"), a section B7 for calculating a drop in line voltage of each segment (hereinafter referred to as a "segment voltage drop calculation section B7"), a section B10 for calculating a drop in line voltage for each instance (hereinafter referred to as an "instance voltage drop calculation section B10"), and a current correction section B12.

These steps will now be described. In step B2, layout data A9 are entered, and the geometry of a power line is determined in consideration of information concerning electrical interconnections. On the basis of the thus-determined geometry of a power line, nodes, change in line width, bends/turns, and switching to another interconnection are identified, and the power line is branched in accordance with identification results, thereby forming segment information B4 pertaining to

respective segments of the power line. The thus-constructed database for the segment information B4 includes the length and width of a line in each segment.

FIG. 30 is a schematic illustration showing the layout data A9 which is input to be entered in step B2. FIG. 31 is a schematic illustration showing for the data base the segment information B4 produced in step B2. Segments 1 through 12 formed as a result of branching of an interconnection are represented by Sg1 through Sg12. The segment information B4 concerning respective segments of the power line, the information being produced in step B2, is entered in step B6, and resistance information B8 concerning the resistance of a line in each segment is produced from information concerning the length and width of a line in each segment and a predetermined resistance parameter assigned to each interconnection layer.

FIG. 32 is a schematic representation showing a data base for the resistance information B8 produced in step B6. In this drawing, the resistance of segment Sg1 of a power line (VDD) is indicated by R1; the resistance of segment Sg2 of the power line is indicated by R2; the resistance of segment Sg3 of the power line is indicated by R3; the resistance of segment Sg4 of the power line is indicated by R4; the resistance of segment Sg5 of the power line is indicated by R5; and the resistance of segment Sg6

of the power line is indicated by R6. In step B3, there are entered information B1 concerning an instantaneously-changing current of each instance produced on the basis of the instantaneously-changing current calculation result 12 (hereinafter referred to simply as "instantaneously-changing current information B1") and the segment information B4 concerning the respective segments of a power line produced in step B2. The electric current of each instance is distributed into current components which flow through the respective segments of the power line. The current components of each instance, which components have been distributed into the respective segments of the power line, are summed, to thereby produce current information B5 for each segment.

FIG. 33 is a schematic representation showing the data base for the current information B5 produced in step B3. In the drawing, electric currents flowing through instances 1 through 3 are indicated by I1 through I3, and electrical currents flowing through segments Sg1 through Sg6 are indicated by Is1 through Is6. In this case, Is1=I1+I2+I3, Is2=I2+I3, Is3=I43, Is4=I1, Is5=I2, and Is6=I3. In step B7, there are entered the current information B5 prepared each of the segments in step B3 and the resistance information B8 prepared for each of the segments in step B6. Information B9 concerning a drop in

line voltage in each segment (hereinafter referred to simply as "voltage drop information B9") is prepared according to Ohm's low.

FIG. 34 is a schematic representation showing the data base for the voltage drop information B9 prepared in step B7. In the drawing, voltage drops in respective segments Sg1 through Sg6 are indicated by $\Delta Vs1$ through $\Delta Vs6$. In this case, $\Delta Vs1=R1\times Is1$; $\Delta Vs2=R2\times Is2$; $\Delta Vs3=R3\times Is3$; $\Delta Vs4=R4\times Is4$; $\Delta Vs5=R5\times Is5$; and $\Delta Vs6=R6\times Is6$. In step B10, there is entered the voltage drop information B9 prepared for each of the segments in step B7. Voltage drops in respective segments of a current flow path of each instance are summed, to thereby produce voltage drop information B11 for each instance.

FIG. 35 is a schematic representation showing the data base for the voltage drop information B11 prepared in step B10. In the drawing, voltage drops arising in instances 1 through 3 are indicated by $\Delta V1$ through $\Delta V3$. In this case, $\Delta V1=\Delta Vs1+\Delta Vs4$; $\Delta V2=\Delta Vs1+\Delta Vs2+\Delta Vs5$; and $\Delta V3=\Delta Vs1+\Delta Vs2+\Delta Vs3+\Delta Vs6$. Here, $\Delta V1$ is expressed as $\Delta V1=R1\times(I1+I2+I3)+R4\times I1$; $\Delta V2$ is expressed as $\Delta V2=R1\times(I1+I2+I3)+R2\times(I2+I3)+R5\times I2$; and $\Delta V3$ is expressed as $\Delta V3=R1\times(I1+I2+I3)+R2\times(I2+I3)+R3\times I3+R6\times I3$.

In step B12, there are entered the voltage drop information B11 prepared for each instance in step B10 and

an I-V table file A10 (or an I-V function) representing the relationship between the amount of electric current and the degree of drop in line voltage, wherewith the instantaneously-changing current calculation result 12 is corrected. As a result, there is produced an instantaneously-changing current calculation result A6 for each instance, the calculation result taking into consideration a drop in line voltage which is dependent on the resistance of a power line.

As mentioned above, the EMI analysis method according to the seventh embodiment takes into consideration a drop in line voltage which is dependent on the resistance of a power line, to thereby correct the instantaneously-changing current calculation result 12 obtained in the first embodiment in consideration of a physical phenomena, such as fluctuations in a line voltage of a real semiconductor integrated circuit. Therefore, the EMI analysis method of the present embodiment can produce a more accurate model of a current waveform, thereby reducing undesired higher harmonic components included in the frequency characteristic of a circuit to be analyzed, the characteristic being determined by means of subjecting the current waveform to FFT processing.

Although the seventh embodiment has referred to the first embodiment, similar results are yielded even when

the technical concept of the present embodiment is applied to any of the second through sixth embodiments.

(Eighth Embodiment)

An EMI analysis method according to an eighth embodiment of the present invention will now be described. FIG. 36 is a block diagram showing the overall flowchart of the EMI analysis method according to the present embodiment. The EMI analysis method according to the present embodiment is identical with the EMI analysis method according to the seventh embodiment described in connection with FIG. 28, except for addition of data C1 and replacement of the voltage drop calculation/instantaneously-changing current correction section A11 by a voltage drop calculation/instantaneously-changing current correction section C2. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the first embodiment are assigned the same reference numerals, and their repeated explanations are omitted.

C1 designates a C-V table file (or a C-V function) representing the relationship between decoupling capacitance existing between a power and the ground and the degree of a drop in line voltage. C2 designates a section for calculating a drop in line voltage and

correcting the result of an instantaneously-changing current being calculated in step 11 (hereinafter referred to as a "voltage drop calculation/instantaneously-changing current correction section"). FIG. 37 is a block diagram showing the flow of processing of the voltage drop calculation/instantaneously-changing current correction section C2 according to the eighth embodiment of the present invention. The function of the voltage drop calculation/instantaneously-changing current correction section C2 will now be described by reference to the accompanying drawings. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the seventh embodiment are assigned the same reference numerals, and their repeated explanations are omitted. Since the data 12 have already been described in detail in connection with the first embodiment, the same reference numeral is assigned to the data 12, and its repeated explanation is omitted.

The voltage drop calculation/instantaneously-changing current correction section C2 is configured such that a section D1 for calculating the capacitance of each segment in a power-to-ground line (hereinafter referred to simply as a "capacitance calculation section D1") is added to the voltage drop calculation/instantaneously-

changing current correction section A11, and the segment voltage drop calculation section B7 is changed to D3. Those sections and their corresponding steps will now be described. In step D1, there is entered the segment information B4 concerning a power line prepared in step B2 in the seventh embodiment. Information D2 concerning the capacitance of each segment in the power-to-ground line is formed from the information concerning the area of an overlap existing between the segments in the power-to-ground line, the information being included in the segment information B4, as well as from a predetermined capacitance parameter assigned to each interconnection layer.

FIG. 38 is a schematic illustration showing the data base for the capacitance information D2 prepared in step D1. In the drawing, a capacitor provided between segments Sg1 and Sg7 is indicated by C1; a capacitor provided between segments Sg2 and Sg8 is indicated by C2; and a capacitor provided between segments Sg3 and Sg9 is indicated by C3. In step D3, there are entered the current information B5 prepared for each segment in step B3 in the seventh embodiment, the resistance information B8 prepared for each segment in step B6 in the seventh embodiment, the C-V table file C1 (or C-V function) representing the relationship between the decoupling

capacitance existing between the power and the ground and the degree of drop in line voltage, and the capacitance information D2 prepared in step D1 with regard to the capacitance of each of the segments in the power-to-ground line. Those information pieces are corrected according to Ohm's law and the C-V table, to thereby produce the voltage drop information B9 for each segment so as to reflect decoupling capacitance as well as the resistance of a power line.

FIG. 39 is a schematic illustration showing the voltage drop information B9 prepared in step D3. In the drawing, a voltage drop arising in segment Sg1 is indicated by $\Delta Vs11$; a voltage drop arising in segment Sg2 is indicated by $\Delta Vs21$; a voltage drop arising in segment Sg3 is indicated by $\Delta Vs31$; a voltage drop arising in segment Sg4 is indicated by $\Delta Vs41$; a voltage drop arising in segment Sg5 is indicated by $\Delta Vs51$; and a voltage drop arising in segment Sg is indicated by $\Delta Vs61$. In this case, there are obtained $\Delta Vs11=f(C1, \Delta Vs1)$, $\Delta Vs21=f(C2, \Delta Vs2)$, $\Delta Vs31=f(C3, \Delta Vs3)$, $\Delta Vs41=\Delta Vs4$, $\Delta Vs51=\Delta Vs5$, and $\Delta Vs61=\Delta Vs6$.

As has been described, the EMI analysis method according to the eighth embodiment newly adopts correction of a current value in response to fluctuations in a line voltage, which would be induced by decoupling capacitance

existing between the power and the ground, in addition to correction of the current value in consideration of a drop in the line voltage, which would be induced by the resistance of a power line. The instantaneously-changing current result 12 obtained for each instance in the first embodiment can be corrected in consideration of physical phenomena, such as fluctuations in a line voltage of a real semiconductor integrated circuit, thereby enabling realization of more accurate modeling of a current waveform. Therefore, the EMI analysis method of the present embodiment can produce a more accurate model of current waveform, thereby reducing undesired higher harmonic components included in the frequency characteristic of a circuit to be analyzed, the characteristic being determined by means of subjecting the current waveform to FFT processing.

Although the eighth embodiment has referred to the first embodiment, similar results are yielded even when the technical concept of the present embodiment is applied to any of the second through sixth embodiments.

(Ninth Embodiment)

An EMI analysis method according to a ninth embodiment of the present invention will now be described. FIG. 40 is a block diagram showing the overall flowchart of the EMI analysis method according to the present

embodiment. The EMI analysis method according to the present embodiment is identical with the EMI analysis method according to the seventh embodiment described in connection with FIG. 28, except that the voltage drop calculation/instantaneously-changing current correction section A11 is replaced by a voltage drop calculation/instantaneously-changing current correction section E1. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the first embodiment are assigned the same reference numerals, and their repeated explanations are omitted. E1 designates a section for calculating a drop in line voltage and correcting the result of an instantaneously-changing current calculation performed in step 11 (hereinafter referred to as a "voltage drop calculation/instantaneously-changing current correction section").

FIG. 41 is a block diagram showing the flow of processing of the voltage drop calculation/instantaneously-changing current correction section E1 according to the ninth embodiment of the present invention. The function of the voltage drop calculation/instantaneously-changing current correction section E1 will now be described by reference to the

accompanying drawings. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis methods according to the seventh and eighth embodiments are assigned the same reference numerals, and their repeated explanations are omitted.

Since the data 12 have already been described in detail in connection with the first embodiment, the same reference numeral is assigned to the data 12, and repeated explanation is omitted. The voltage drop calculation/instantaneously-changing current correction section E1 is configured by means of removing, from the voltage drop calculation/instantaneously-changing current correction section C2 employed in the eighth embodiment, the segment current calculation section B3 for calculating an electric current flowing through each segment, the voltage drop calculation section D3 for calculating a drop in the voltage of each segment, and the instance voltage drop calculation section B10 for calculating a drop in the voltage of each instance; and newly adding a transient analysis section F1 to the same.

These sections and their corresponding steps will now be described. In step F1, there are entered the instantaneously-changing current information B1 prepared for each instance from the instantaneously-changing

current calculation result 12 in step 11, the resistance information B8 prepared for each segment in step B6 in the eighth embodiment, and the capacitance information D2 concerning a capacitor provided between segments prepared in step D1 in the eight embodiment. Through a simulation performed by a transient analysis simulator typified by SPICE, there is produced voltage drop information B11 concerning a voltage drop of each instance.

As has been described, under the EMI analysis method according to the ninth embodiment, the resistance of a power line and fluctuations in a line voltage, which would be induced by decoupling capacitance existing between the power line and ground, are determined through use of a transient analysis simulator. Physical phenomena, such as fluctuations in a line voltage of a real semiconductor integrated circuit, can be faithfully reflected n the instantaneously-changing current result 12 obtained for each instance in the first embodiment. Therefore, the EMI analysis method of the present embodiment enables materialization of highly-accurate EMI analysis as described in the background art. Further, there can be realized high-speed EMI analysis which can be applied to a large-level circuit.

Although the ninth embodiment has referred to the first embodiment, similar results are yielded even when

the technical idea of the present embodiment is applied to any of the second through sixth embodiments.

(Tenth Embodiment)

An EMI analysis method according to a tenth embodiment of the present invention will now be described. In the second through ninth embodiments, an instantaneously-changing current of each cell is calculated from event information concerning each cell, the information being output from a logic simulator, and the thus-calculated instantaneously-changing current is modeled as a rectangular waveform, thereby determining change in electric current. However, so long as the waveform of an instantaneous electric current is modeled as a triangular wave, a more realistic change in electric current can be determined. By way of example, there will now be described an EMI analysis method comprising the steps of:

calculating a peak value such that an instantaneously-changing electric current becomes equal to the area of a triangular wave;

modeling an instantaneously-changing electric current as a triangular wave having the peak value and a certain width, to thereby calculate a more realistic change in electric current; and

subjecting the result of calculation of an electric

waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

FIG. 42 shows an instantaneous electric current and a modeled triangular wave according to the present embodiment. In the drawing, "i" denotes an instantaneously-changing current; and "t" denotes a current processing time. Further, "W" denotes the width of a triangular wave serving as a model of an instantaneously-changing current and corresponds to a constant. An appropriate value has been determined as a constant beforehand. Reference symbol "h" denotes the height of a triangular wave and is calculated on the basis of "i" and "W." An electric current at time t+x is expressed by Eq.5 provided below.

$$h(c,i)=\left[\frac{h(c1,i1)(c2-c)}{(c2-c1)}+\frac{h(c2,i1)(c-c1)}{(c2-c1)}\right]\left(\frac{i2-i}{i2-i1}\right)+\left[\frac{h(c1,i2)(c2-c)}{(c2-c1)}+\frac{h(c2,i2)(c-c1)}{(c2-c1)}\right]\left(\frac{i-i1}{i2-i1}\right)$$

... (5)

Further, an electric current at time t-x is also expressed by Eq.5.

The overall flow of processing of the EMI analysis method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 43 is a detailed block diagram showing the

current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment. Reference numeral 100 denotes a triangular waveform height calculation section for calculating the height of a triangular wave such that the area of a triangular wave serving as a model of an

instantaneously-changing current becomes equal to an instantaneously-changing current. Reference numeral 101 denotes a triangular-waveform-shaping section for modeling the instantaneously-changing current result 12 into a triangular wave having a constant width.

FIG. 44 is a flowchart of processing pertaining to the triangular-waveform-shaping section 101, including processing pertaining to the triangular waveform height calculation section 100. The following processing is iterated on a per-event basis until calculation of a current waveform is completed (step 1100). The area of a triangular wave is Wxh/2 and assumes a value of an instantaneously-changing current "i." The height "h" of a triangular wave is calculated from 2xi/W (step 1101). Reference symbol "i" denotes an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. This processing corresponds to processing pertaining to the triangular waveform height calculation section 100. Until variable "x" changes from 0 to W/2, h(c, i) expressed by Eq.5 is added to I(t+x) and I(t-x). Further, Δt is added to variable "x" (steps 1102 and 1103). Here, I(t+x) denotes total electric current flowing through all the cells at time t+x, and I(t-x) denotes total electric current flowing through all the cells at time t-x. This processing corresponds to

processing pertaining to the triangular-waveform-shaping section 101.

The current wave calculation result 8 can be obtained by means of the flow of a triangular waveform height calculation operation and a triangular-waveform-shaping operation. FIG. 45 shows an example current wave calculation result 8 at time W=5 in the instantaneously-changing current calculation result shown in FIG. 3. The FFT processing section 9 subjects the waveform to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Eleventh Embodiment)

An EMI analysis method according to an eleventh embodiment of the present invention will now be described. In the second through ninth embodiments, an instantaneously-changing current of each cell is calculated from event information concerning each cell, the information being output from a logic simulator, and the thus-calculated instantaneously-changing current is modeled as a rectangular waveform, thereby determining change in electric current. However, so long as the waveform of an instantaneous electric current is modeled as a multi-order-function wave, a more realistic change in electric current can be determined. By way of example,

there will now be described an EMI analysis method comprising the steps of:

calculating a peak value such that an instantaneously-changing electric current becomes equal to the area of a triangular wave;

modeling an instantaneously-changing electric current as a multi-order-function having the peak value and a given width, to thereby calculate a more realistic change in electric current; and

subjecting the result of calculation of an electric waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

[0135]

FIG. 46 shows an instantaneous electric current and a modeled multi-order-function according to the present embodiment. In the drawing, "i" denotes an instantaneously-changing current; and "t" denotes a current processing time. Further, "W" denotes the width of a multi-order-function wave serving as a model of an instantaneously-changing current and corresponds to a constant. An appropriate value has been determined as a constant beforehand. Reference symbol "h" denotes the height of a multi-order-function wave and is calculated on the basis of "i" and "W." A multi-order-function wave

serving as a model in the present embodiment is expressed by Eq.6 provided below.

$$y = a(x-W)^2(x+W)^2 \ldots (6).$$

The width of a multi-order-function wave model is taken as "2 x W."

According to Eq.6, the height "h" of a multi-order-function wave model is determined when x=0 and is expressed by Eq.7 provided below.

$$h = a \times W^4 \ldots (7).$$

The area of the multi-order-function wave model is expressed by Eq.8 provided below.

$$S = \frac{16}{15} a \times W^5 \ldots (8).$$

Since the thus-defined area becomes equal to the instantaneously-changing current value "i," "a" is expressed though use of "W" and "i" as Eq.9 provided below.

$$a = \frac{15}{16 \times W^5} i \ldots (9).$$

As a result of calculation of "a" through use of Eq.9, the height "h" of a multi-order-function wave serving as a model is determined. Let W=2.5 and i=100, then a=0.96 is derived from Eq.9. Eq.7 consequently gives h=37.5. Further, let W=2.5 and i=50, then a=0.48 is derived from Eq.9. Eq.7 consequently gives h=18.75.

The overall flow of processing of the EMI analysis

method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 47 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11.

FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave

calculation operation of the first embodiment.

Reference numeral 110 denotes a multi-order-function waveform height calculation section for calculating the height of a multi-order-function wave such that the area of a multi-order-function wave serving as a model of an instantaneously-changing current becomes equal to an instantaneously-changing current. Reference numeral 111 denotes a multi-order-function waveform-shaping section for modeling the instantaneously-changing current result 12 as a multi-order-function wave having a constant width.

[0142]

FIG. 48 is a flowchart of processing pertaining to the triangular-waveform-shaping section 101, including processing pertaining to the triangular waveform height calculation section 100. The following processing is iterated on a per-event basis until calculation of a current waveform is completed (step 1110). A peak-value-dependent coefficient "a" of a multi-order-function is calculated from Eq.9 (step 1111). Reference symbol "i" denotes an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis, and "W" is a constant which is dependent on the width of a wave. This processing corresponds to processing pertaining to the multi-order-function waveform height calculation

section 110.

Until variable "x" changes from -W to W, multi-order-function "y" expressed by Eq.6 is added to I(t+x). Further, Δt is added to variable "x" (steps 1112 and 1113). Here, I(t+x) denotes total electric current flowing through all the cells at time t+x. This processing corresponds to processing pertaining to the multi-order-function waveform-shaping section 111.

The current wave calculation result 8 can be obtained by means of the flow of a multi-order-function waveform height calculation operation and a multi-order-function waveform-shaping operation. FIG. 49 shows an example current wave calculation result 8 at time W=2.5 in the instantaneously-changing current calculation result shown in FIG. 3. The FFT processing section 9 subjects the waveform to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Twelfth Embodiment)

An EMI analysis method according to a twelfth embodiment of the present invention will now be described. In the second through ninth embodiments, an instantaneously-changing current of each cell is calculated from event information concerning each cell, the information being output from a logic simulator, and

the thus-calculated instantaneously-changing current is modeled as a rectangular waveform, thereby determining change in electric current. However, so long as the waveform of an instantaneous electric current is modeled as a Gauss function wave, a more realistic change in electric current can be determined.

By way of example, there will now be described an EMI analysis method comprising the steps of:

calculating the height and width of a Gauss function wave through use of a global table representing the relationship between an instantaneously-changing electric current and a Gauss function serving as a model, and another table representing the relationship between the instantaneously-changing current and the duration of the Gauss function wave;

modeling the instantaneously-changing electric current as a Gauss function wave, to thereby calculate a more realistic change in electric current; and

subjecting the result of calculation of an electric waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

FIG. 50 shows an instantaneous electric current and a modeled Gauss function according to the present embodiment. In the drawing, "i" denotes an

instantaneously-changing current; "t" denotes a current processing time; and "h" denotes the height of a Gauss function wave serving as a model and calculated from a global table representing the relationship between an instantaneously-changing current and the height of a Gauss function serving as a model.

FIG. 51 is a graph showing an example global i-h table representing the relationship between an instantaneously-changing current value and the height of a Gauss function waveform. The table shows the value of "h" at each of certain points "i." The table indicates that "h" assumes a value of 0 at i=0, a value of 10 at i=50, and a value of 40 at i=100. In reality, the value of "i" changes continuously, and hence the table is expressed as a graph plotting points provided in the table. The value of "h" [i.e., h(i)] at a certain value of "i" is expressed by Eq.2 provided below, through linear interpolation of the values of two points closest to "i" provided in the i-h table: one point has lower values (i1, h1), and the other point has higher values (i2, h2). Here, "w" designates the width of a Gauss function serving as a model, and the width "w" of a Gauss function is calculated through use of a global table representing the relationship between an instantaneously-changing current and the width of a Gauss function serving as a model.

FIG. 52 is a graph showing an example global i-w table representing the relationship between an instantaneously-changing current value and the width "w" of a rectangular waveform. The table shows the value of "w" at each of certain points "i." The table indicates that "w" assumes a value of 0 at i=0, a value of 1 at i=20, and a value of 1.5 at i=100. In reality, the value of "i" changes continuously, and hence the table is expressed as a graph plotting points provided in the table.

The value of "w" [i.e., w(i)] at a certain value of "i" is expressed by Eq.10 provided below, through linear interpolation of the values of two points closest to "i" provided in the i-w table: one point has lower values (i1, w1), and the other point has higher values (i2, w2).

$$w(i) = \frac{w2 - w1}{i2 - i1}(i - i1) + w1 \quad \ldots \quad (10)$$

In the present embodiment, the Gauss function serving as a model is expressed by Eq.10. This function is called a Gaussian function. Let x=0, Eq.10 provides "h," which represents the height of a Gaussian function wave. From Eq.10, let x=3xW, there is derived a value of 0.0001xh (i.e., 0.01% of the height of a Gaussian function wave). This value is taken as a limit on the width of a Gaussian function serving as a model, and the width of the Gaussian function is taken as "6xw."

The overall flow of processing of the EMI analysis method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 53 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11.

FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot

be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment. Reference numeral 40 designates a global i-h table representing the relationship between an instantaneously-changing current value and the height of a Gaussian function wave (see FIG. 51). Reference numeral 120 designates a Gaussian function waveform height calculation section for calculating, from an instantaneously-changing current value and the table i-h 40, a peak value of a Gaussian function serving as a model.

Reference numeral 121 designates a global i-w table representing the relationship between an instantaneously-changing current value and the width of a Gaussian function wave (see FIG. 52). Reference numeral 122 designates a Gaussian function waveform width calculation section for calculating the width of a Gaussian function wave from the instantaneously-changing current value and the i-w table 121. Reference numeral 123 denotes a Gaussian function waveform-shaping section for modeling the instantaneously-changing current result 12 as a Gaussian function wave having a peak value calculated by the Gaussian function waveform height calculation section 120 and a width calculated by the Gaussian function waveform width calculation section 122.

FIG. 54 shows the flowchart of processing pertaining to the Gaussian function waveform-shaping section 123, including processing pertaining to the Gaussian function waveform height calculation section 120 and processing pertaining to the Gaussian function waveform width calculation section 122. First, the i-h table 40 is read (step 1120), and the i-w table 121 is read (step 1121). The processing provided below is iterated on a per-event basis until calculation of a current waveform is completed (step 1122). There are extracted two points closest to "i" provided in the i-h table 40: one point has lower values (i1, h1), and the other point has higher values (i2, h2) (step 1123). Here, reference symbol "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis.

In connection with the table shown in FIG. 51, in the case of i=50, there are obtained (i1, h1)=(0, 0) and (i2, h2)=(50, 5). In the case of i=100, there are obtained (i1, h1)=(50, 5) and (i2, h2)=(100, 20). From Eq. 2, there is calculated the height "h" of the Gaussian function wave (step 1124). In connection with the table shown in FIG. 51, in the case of i=50, there is obtained h(50)=10. In the case of i=100, there is obtained h(100)=40. This processing corresponding to processing pertaining to the

Gaussian function waveform height calculation section 120.

There are extracted two points closest to "i" provided in the i-w table 121: one point has lower values (i1, w1), and the other point has higher values (i2, w2) (step 1125). Here, reference symbol "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. In connection with the table shown in FIG. 52, in the case of i=50, there are obtained (i1, w1)=(0, 0) and (i2, w2)=(20, 1). In the case of i=100, there are obtained (i1, w1)=(20, 1) and (i2, w2)=(100, 1.5).

Eq.10 provides the width "w" of the Gaussian function wave (step 1126). In connection with the table shown in FIG. 52, in the case of i=50, there is obtained w(50)=1.3. In the case of i=100, there is obtained w(100)=1.5. The processing pertaining to steps 1125 and 1126 corresponds to processing pertaining to the Gaussian function waveform width calculation section 122.

[0158]

A function expressed by Eq.11 provided below is added to I(t+x) until variable "x" changes from -3xW to 3xW, and Δt is added to "x" (steps 1127 and 1128).

$$y = h \times e^{-\left(\frac{x}{w}\right)^2} \quad \ldots \quad (11).$$

Here, I(t+x) represents total current flowing through all the cells at time "t+x." This processing corresponds to processing pertaining to the Gaussian function waveform-shaping section 123.

[0159]

The current wave calculation result 8 can be obtained by means of the flow of a Gaussian function waveform height calculation operation, a Gaussian function waveform width calculation operation, and a Gaussian function waveform-shaping operation. FIG. 55 shows an example current waveform calculation result 8 as the result of calculation of an instantaneously-changing current shown in FIG. 3, the calculation result being obtained in a case where the table shown in FIG. 51 is used as the i-h table 40 and the table shown in FIG. 52 is used as the i-w table 121. The current wave calculation result 8 is subjected to an FFT operation by the FFT processing section 9, to thereby determine the frequency characteristic of an EMI component. Thus, there can be obtained an EMI analysis result 10.

(Thirteenth Embodiment)

An electromagnetic interference (EMI) analysis method according to a thirteenth embodiment of the present invention will now be described. The EMI analysis method according to the present embodiment is characterized by

modeling an instantaneously-changing current while information concerning estimation of a current waveform (hereinafter referred to simply as "current waveform estimation information") is separated into an element dependent on a short circuit current (also called "short circuit-current-dependent element") and another element dependent on a charge current (also called "charge-current-dependent element"). The expression "short circuit current" used herein means an electric current which flows from the source terminal to the drain terminal in each of a p-channel MOS transistor (hereinafter abbreviated "p-MOS transistor") and an n-channel MOS transistor (hereinafter abbreviated "n-MOS transistor") in a case where the p-MOS and n-MOS transistors are instantaneously and simultaneously brought into an active state as a result of a change arising in a signal appearing at the gate terminal of a CMOS transistor constituting a circuit element. The expression "charge current" means an electric current which flows when electric charge is stored in or discharged from an output load capacitor of a circuit element. A short circuit current arises substantially simultaneous with occurrence of a change in an input signal, and a charge current flows together with a change in an output signal at a slight time lag from the time when change has arisen in an input signal.

Accordingly, estimation of a more accurate current waveform becomes feasible by means of separate handling of the short circuit-current-dependent element of the current waveform estimation information and the charge-current-dependent element.

FIG. 56 shows the configuration of the EMI analysis method according to the present embodiment using a technique of averaging a short circuit current and a charge current by means of dividing by a discrete width.

A system used with the EMI analysis method shown in FIG. 56 has means for analyzing the amount of current (hereinafter referred to as "amount-of-current analysis means"), the amount-of-current analysis means comprising circuit-connection information storage means 7301 for storing information concerning circuit interconnections; pattern-of-signal-change storage means 7302 for storing a pattern of signal change; element-current storage means 7303 for storing the amount of electric current flowing through an element; basic-information-for-estimating-current storage means 7306 for storing basic information concerning estimation of an electric current; total-amount-of-current storage means 7304 for storing the total amount of current flowing through an element; and total-amount-of-current calculation means 7305 for calculating the total amount of electric current.

These means constituting the EMI analysis method shown in FIG. 56 will now be described. There will now be described procedures for calculating the total amount of electric current shown in FIG. 58 from circuit connection information shown in FIG. 110, a pattern of signal change shown in FIG. 111, and basic information concerning estimation of an electric current shown in FIG. 59. The amount-of-current analysis means comprising circuit-connection information storage means 7301 is identical with the circuit connection information storage means 1001 described in connection with the background art, and the pattern-of-signal-change storage means 7302 is identical with the signal pattern storage means 1002 described in connection with the background art. Hence, their repeated explanations are omitted for brevity.

The element-current storage means 7303 stores information concerning the amount of electric current flowing through an element; that is, information concerning the total amount of electric current flowing when single change arises in an external terminal of each element, while the information is divided into a short circuit current component and a charge current component. The information concerning the amount of electric current flowing through an element, such as that shown in FIG. 57, has been stored in the element-current storage means 7303

beforehand. Reference numeral 7401 denotes the amount of short circuit current which flows when a change arises in a signal appearing at a clock input terminal CK of a flip-flop FF. Reference numeral 7402 denotes the amount of charge current which flows when a change arises in a signal appearing at a clock input terminal CK of the flip-flop FF. Reference numeral 7403 denotes the amount of short circuit current which flows when a change arises in a signal appearing at an output terminal Q of the flip-flop FF. Reference numeral 7404 denotes the amount of charge current which flows when a change arises in a signal appearing at the output terminal Q of the flip-flop FF. Reference numeral 7405 denotes the amount of short circuit current which flows when a change arises in a signal appearing at an output terminal Y of a buffer BUF. Reference numeral 7406 denotes the amount of charge current which flows when a change arises in a signal appearing at the output terminal Y of the buffer BUF. The basic-information-for-estimating-current storage means 7306 stores the discrete width of a short circuit current and the discrete width of a charge current in the form shown in FIG. 59. The basic information concerning estimation of an electric current has a discrete width to be used for averaging the total amount of electric current which flows in response to occurrence of a change in a signal, as in

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the case of the information employed in the first embodiment. However, in contrast with the information employed in the first embodiment, the basic information concerning estimation of an electric current comprises two pieces of information: that is, information 7601 concerning the discrete width of a short circuit current, and information 7602 concerning the discrete width of a charge current. Information 7601 represents the discrete width of a short circuit current, and information 7602 represents the discrete width of a charge current.

The total-amount-of-current calculation means 7305 operates according to a flowchart such as that shown in FIG. 60. In contrast with the conventional method, the flowchart shown in FIG. 60 of the EMI analysis method of the present embodiment is additionally provided with a processing operation for averaging the calculated short circuit current by means of dividing by the discrete width thereof and averaging the calculated charge current by means of dividing by the discrete width thereof (step 7706). In step 7701, there is read the circuit connection information, which is shown in FIG. 110 and is stored in the circuit-connection information storage means 7301. In step 7702, there is read the pattern of a change in a signal, the pattern being stored in the pattern-of-signal-change storage means 7302. In step 7703, there is

read information concerning the amount of electric current flowing through an element, the information being stored in the element-current storage means 7303 and shown in FIG. 57.

In step 7704, there is read the information concerning estimation of a current, the information being stored in the basic-information-for-estimating-current storage means 7306 and shown in FIG. 59. In step 7705, the pattern of a change in a signal shown in FIG. 111 is imparted to the circuit connection information shown in FIG. 110, to thereby enable propagation of a signal. In a case where a change arises in a signal appearing at an external terminal of a circuit element, the element being described in the information concerning the amount of electric current flowing through an element, a short circuit current component and a charge current component included in the electric current flowing through the external terminal are added, at respective points in time, to the short circuit current component and the charge current component included in the information concerning the total amount of electric current (simply called as "total current information"), respectively.

[0166]

In step 7706, the result of an electric current being averaged by means of dividing by the discrete width stored

in the information concerning estimation of a current shown in FIG. 59 is added to the short circuit current component included in the total current information. The result of an electric current being averaged by means of dividing by the discrete width stored in the information concerning estimation of a current shown in FIG. 59 is added to the charge current component included in the total current information. In step 7707, after propagation of a signal, information concerning the total amount of electric current calculated at each points in time shown in FIG. 58 is stored in the total-amount-of-current storage means 7304. As a result, there is obtained a current waveform, such as that shown in FIG. 58, which is more realistic than the current waveform obtained by the conventional method shown in FIG. 14.

[0167]

(Fourteenth Embodiment)

An EMI analysis method according to a fourteenth embodiment of the present invention will now be described. The present embodiment describes an EMI analysis method comprising the steps of:

characterizing a peak current of a cell according to the type of cell and the amount of instantaneously-changing current of each event, to thereby calculate an instantaneously-changing current of each cell from event

information, the information being output from a logic simulator;

modeling the instantaneously-changing current as a rectangular waveform whose width is calculated such that a peak value corresponds to the peak current of the rectangular waveform and such that the instantaneously-changing current becomes equal to the area of the rectangular waveform, to thereby calculate a more realistic change in an electric current; and

subjecting the result of calculation of a current waveform to FFT processing, to thereby determine the frequency characteristic of an EMI component arising in a circuit of interest.

FIG. 15 shows an instantaneously changing current and a modeled rectangular waveform according to the present embodiment. Here, "i" denotes an instantaneously-changing current, and "t" denotes a current processing time.

The overall flow of processing of the EMI analysis method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 61 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an

instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment.

Reference numeral 130 denotes a peak current library. A peak current of each cell is characterized according to the type of cell, and the thus-characterized value is stored in the peak current library 130. Reference numeral 131 designates a sixth rectangular waveform height

calculation section for extracting, from the peak current library 130, a peak value of a rectangular waveform serving as a model. Reference numeral 132 designates a sixth rectangular waveform width calculation section for calculating the width of a rectangular waveform, from the peak value extracted by the sixth rectangular waveform height calculation section 131 and the instantaneously-changing current value, such that the instantaneously-changing current becomes equal to the area of the rectangular waveform. Reference numeral 133 denotes a sixth rectangular waveform-shaping section for modeling the instantaneously-changing current calculation result 12 as a rectangular waveform, the height of the rectangular waveform corresponding to the peak value extracted by the sixth rectangular waveform height calculation section 131, and the width of the rectangular waveform corresponding to the width calculated by the sixth rectangular waveform width calculation section 132.

FIG. 62 shows the flowchart of processing pertaining to the sixth rectangular waveform-shaping section 133, including processing pertaining to the sixth rectangular waveform height calculation section 131 and processing pertaining to the sixth rectangular waveform width calculation section 132. First, the peak current library

130 is read (step 1130). The following processing is iterated on a per-event basis until calculation of a current waveform is completed (step 1130). A peak current of an instance which is an object of EMI analysis is extracted from the peak current library 130, and the peak current is taken as the height "h" of a rectangular waveform (step 1132). This processing corresponds to processing pertaining to the sixth rectangular waveform height calculation section 131.

The area of the rectangular waveform is defined by "w x h." The width "w" of a rectangular waveform is calculated on the basis of "w = i/h" (step 1133). Reference symbol "i" denotes an instantaneously-changing current of a cell of an instance, the instance being an object of EMI analysis. Reference symbol "h" denotes the height "h" of a rectangular waveform calculated through processing pertaining to the sixth rectangular waveform height calculation section 131. This processing corresponds to processing pertaining to the sixth rectangular waveform width calculation section 132. Next, "h" is added to I(t+x) until a variable "x" changes from -W/2 to W/2, and Δt is added to "x" (steps 1134 and 1135). I(t+x) corresponds to total electric current flowing through all the cells at time t+x. This processing corresponds to processing pertaining to the sixth

rectangular waveform-shaping section 133.

The current wave calculation result 8 can be obtained by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. The FFT processing section 9 subjects the current waveform calculation result 8 to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Fifteenth Embodiment)

An EMI analysis method according to a fifteenth embodiment of the present invention will now be described. The present embodiment describes an EMI analysis method comprising the steps of:

characterizing the relationship between a slew in a waveform input to each cell and a peak current of the cell, according to the type of cell, and the amount of instantaneously-changing current for each event, to thereby calculate an instantaneously-changing current of each cell from event information concerning each cell, the information being output from a logic simulator;

modeling the instantaneously-changing current as a rectangular waveform whose width is calculated such that a peak current taking into consideration a slew in the

waveform input to the cell corresponds to a peak current of the waveform and such that the instantaneously-changing current becomes equal to the area of the rectangular waveform, to thereby calculate a more realistic change in an electric current; and

subjecting the result of calculation of a current waveform to FFT processing, to thereby determine the frequency characteristic of an EMI component arising in a circuit of interest.

FIG. 15 shows an instantaneously changing current and a modeled rectangular waveform according to the present embodiment. Here, "i" denotes an instantaneously-changing current, and "t" denotes a current processing time. Further, "h" denotes the height of a rectangular waveform. The height "h" of a rectangular waveform is calculated from a library which characterizes the relationship between a slew in the waveform input to each cell and the height of a rectangular waveform. Reference symbol "w" denotes the width of a rectangular waveform, and the width "w" of a rectangular waveform is calculated from the height "h" calculated previously and the instantaneously-changing current "i." The library characterizing the relationship between a slew in an input waveform and the height of a rectangular waveform is prepared according to the type of cell in the form of an

s-h table.

FIG. 63 shows an example s-h table and a graph plotting the table. Here, "s" denotes a slew in a waveform input to an instance which is an object of EMI analysis. The table shows the value of "h" at each of certain points "s." The table indicates that "h" assumes a value of 0 at s=0, a value of 5 at s=1, and a value of 20 at s=2. In reality, the value of "s" changes continuously, and hence the table is expressed as a graph plotting points provided in the table. The value of "h" [i.e., h(s)] at a certain value of "s" is expressed by Eq.12 provided below, through linear interpolation of the values of two points closest to "s" provided in the s-h table: one point has lower values (s1, h1), and the other point has higher values (s2, h2).

$$h(s) = \frac{h2 - h1}{s2 - s1}(s - s1) + h1 \quad \ldots \quad (12)$$

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 64 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell

from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment.

In the present embodiment, an s-h table library 140 characterizes the relationship between a slew in a waveform input to each cell and the height of a rectangular waveform (see FIG. 63). Reference numeral 51 designates Slew data describing a slew in a waveform input to each instance. Reference numeral 141 designates a seventh rectangular waveform height calculation section for

extracting a slew in a waveform input to each instance, the instance being an object of EMI analysis, from the Slew data 51, and calculating a peak value of a rectangular waveform serving as a model, from the s-h table library 140 and the thus-extracted slew. Reference numeral 142 designates a seventh rectangular waveform width calculation section for calculating the width of a rectangular waveform from the peak value calculated by the seventh rectangular waveform height calculation section 141 and from the instantaneously-changing current, such that the area of the rectangular waveform becomes equal to the instantaneously-changing electric current. A seventh rectangular waveform-shaping section 143 models the instantaneously-changing current calculation result 12 as a rectangular waveform, the height of the rectangular waveform corresponding to the peak value of the rectangular waveform calculated by the seventh rectangular waveform height calculation section 141, and the width of the rectangular waveform corresponding to the width calculated by the seventh rectangular waveform width calculation section 142.

FIG. 65 is a flowchart showing processing pertaining to the seventh rectangular waveform-shaping section 143, including processing pertaining to the seventh rectangular waveform height calculation section 141 and

processing pertaining to the seventh rectangular waveform width calculation section 142. First, the s-h table library 140 is read (step 1140). The Slew data 51 are read (step 1141). Next, the subsequent processing operations are iterated on a per-event basis until the current waveform calculation operation is completed (step 1142). Two points closest to "s"; (s1, h1) and (s2, h2), are extracted from the s-h library table 140. Reference symbol "s" denotes a slew in an input waveform, the slew being extracted from the Slew data 51 concerning an instance which is an object of EMI analysis.

In connection with the table shown in FIG. 63, in the case where s=1.2, the two points closest to s=1.2 are (s1, h1) = (1, 5) and (s2, h2) = (2, 20) (step 1143). The height "h" of a rectangular waveform is calculated according to Eq.11 (step 1144). In the table shown in FIG. 63, in the case where s=1.2, h(1.2)=8. This processing; i.e., processing pertaining to steps 1143 and 1144, corresponds to processing pertaining to the seventh rectangular waveform height calculation section 141.

The area of a rectangular waveform is defined as "w x h." The width "w" of a rectangular waveform is calculated from w=i/h (step 1145). Reference symbol "i" denotes the value of an instantaneously-changing current of a cell of an event, the event being an object of EMI

analysis. Reference symbol "h" denotes the height of a rectangular waveform calculated by the seventh rectangular waveform height calculation section 141. This processing corresponds to processing pertaining to the seventh rectangular waveform width calculation section 142. Next, "h" is added to I(t+x) until variable "x" changes from -W/2 to W/2, and Δt is added to variable "x" (steps 1146 and 1147). I(t+x) denotes total electric current flowing through all the cells at time "t+x." This processing corresponds to processing pertaining to the seventh rectangular waveform-shaping section 143.

The current wave calculation result 8 can be obtained by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. The FFT processing section 9 subjects the current waveform calculation result 8 to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Sixteenth Embodiment)

An EMI analysis method according to a sixteenth embodiment of the present invention will now be described. The present embodiment describes an EMI analysis method

comprising the steps of:

characterizing the relationship between an output load capacitance of each cell and a peak current of the cell, according to the type of cell, and the amount of instantaneously-changing current for each event, to thereby calculate an instantaneously-changing current of each cell from event information concerning each cell, the information being output from a logic simulator;

modeling the instantaneously-changing current as a rectangular waveform whose width is calculated such that a peak current taking into consideration of the output load capacitance of the cell corresponds to a peak current of the waveform and such that the instantaneously-changing current becomes equal to the area of the rectangular waveform, to thereby calculate a more realistic change in an electric current; and

subjecting the result of calculation of a current waveform to FFT processing, to thereby determine the frequency characteristic of an EMI component arising in a circuit of interest.

FIG. 15 shows an instantaneously changing current and a modeled rectangular waveform according to the present embodiment. Here, "i" denotes an instantaneously-changing current, and "t" denotes a current processing time. Further, "h" denotes the height

of a rectangular waveform. The height "h" of a rectangular waveform is calculated from a library which characterizes the relationship between the output load capacitance of each cell and the height of a rectangular waveform. Reference symbol "w" denotes the width of a rectangular waveform, and the width "w" of a rectangular waveform is calculated from the height "h" calculated previously and the instantaneously-changing current "i." The library characterizing the relationship between the output load capacitance and the height of a rectangular waveform is prepared according to the type of cell in the form of a c-h table.

FIG. 66 shows an example c-h table and a graph plotting the table. Here, "s" denotes an output load capacitance of an instance which is an object of EMI analysis. The table shows the value of "h" at each of certain points "c." The table indicates that "h" assumes a value of 0 at c=0, a value of 5 at c=10, and a value of 20 at c=20. In reality, the value of "c" changes continuously, and hence the table is expressed as a graph plotting points provided in the table. The value of "h" [i.e., h(c)] at a certain value of "c" is expressed by Eq.13 provided below, through linear interpolation of the values of two points closest to "c" provided in the s-h table: one point has lower values (c1, h1), and the other point

has higher values (c2, h2).

$$h(c)=\frac{h2-h1}{c2-c1}(c-c1)+h1 \quad \ldots \quad (13)$$

The overall flow of processing pertaining to the EMI analysis method of the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 67 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11.

FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current

calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment. Reference numeral 150 designates a table library. The c-h table library 150 is made up of a c-h table library (see FIG. 66) characterizing the relationship between the previously-described output load capacitance of each cell and the height of a rectangular waveform. Reference numeral 61 designates capacitance data describing an output load capacitance of each instance. Reference numeral 151 designates an eighth rectangular waveform height calculation section for extracting an output load capacitance of an instance, the instance being an object of EMI analysis, from the capacitance data 61 and calculating a peak value of a rectangular waveform serving as a model, from the c-h table library 150 and the thus-extracted output load capacitance. Reference numeral 152 designates an eighth rectangular waveform width calculation section for calculating the width of a rectangular waveform from the peak value calculated by the eighth rectangular waveform height calculation section 151 and from the instantaneously-changing current, such that the area of the rectangular waveform becomes equal

to the instantaneously-changing electric current. An eighth rectangular waveform-shaping section 153 models the instantaneously-changing current calculation result 12 as a rectangular waveform, the height of the rectangular waveform corresponding to the peak value of the rectangular waveform calculated by the eighth rectangular waveform height calculation section 151, and the width of the rectangular waveform corresponding to the width calculated by the eighth rectangular waveform width calculation section 152.

FIG. 68 is a flowchart showing processing pertaining to the eighth rectangular waveform-shaping section 153, including processing pertaining to the eighth rectangular waveform height calculation section 151 and processing pertaining to the eighth rectangular waveform width calculation section 152. First, the c-h table library 150 is read (step 1150). The capacitance data 61 are read (step 1151).

Next, the subsequent processing operations are iterated on a per-event basis until the current waveform calculation operation is completed (step 1152). Two points closest to "c"; (c1, h1) and (c2, h2), are extracted from the c-h library table 150. Reference symbol "c" denotes a slew in an input waveform, the slew being extracted from the capacitance data 61 concerning an

instance which is an object of EMI analysis.

In connection with the table shown in FIG. 66, in the case where c=12, the two points closest to c=12 are (c1, h1) = (1, 5) and (c2, h2) = (20, 20) (step 1153). The height "h" of a rectangular waveform is calculated according to Eq.12 (step 1154). In the table shown in FIG. 66, in the case where c=12, h(12)=8. This processing; i.e., processing pertaining to steps 1153 and 1154, corresponds to processing pertaining to the eighth rectangular waveform height calculation section 151.

This processing corresponds to processing pertaining to the eighth rectangular waveform width calculation section 152. Next, "h" is added to I(t+x) until variable "x" changes from -W/2 to W/2, and Δt is added to variable "x" (steps 1156 and 1157). I(t+x) denotes total electric current flowing through all the cells at time

"t+x." This processing corresponds to processing pertaining to the eighth rectangular waveform-shaping section 153.

The current wave calculation result 8 can be obtained by means of the flow of a rectangular waveform height calculation operation, a rectangular waveform width calculation operation, and a rectangular waveform-shaping operation. The FFT processing section 9 subjects the

current waveform calculation result 8 to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Seventeenth Embodiment)

An electromagnetic interference (EMI) analysis method according to a seventeenth embodiment of the present invention will now be described. Among operations related to EMI analysis, the present embodiment describes particularly extraction of a characteristic of EMI and calculation of the amount of an electric current, in the case where a circuit element is a composite cell formed by combination of a plurality of logic elements. In a composite cell, an electric current flows every time each of logic elements constituting the circuit element is activated. A logic element provided in a circuit element is activated with a time lag unique to the logic element.

Specifically, when a change arises in an input to a circuit element, an electric current flows many times within the circuit element. In a circuit element including logic elements in combination as shown in FIG. 108, 1N1 is changed with a lag of a gate P1 provided in a cell (provided that the lag is 1ns) from the time changes have arisen in terminals A and B. Further, Y is changed

with a lag of a gate P2 provided in the cell (provided that the lag is 1ns) from the time a change has arisen in 1N1. In a case where a pattern of signal change shown in FIG. 69 is imparted to the circuit element (cell), there arises a current waveform such as that shown in FIG. 70.

According to the conventional gate-level EMI analysis method, the total amount of electric current flowing through each circuit element is considered to be dissipated with an involved time lag until a signal appears at an output pin of the circuit element. For instance, in a case where a pattern of signal change shown in FIG. 69 is imparted to a circuit shown in FIG. 73, the circuit employing a circuit element shown in FIG. 108, there is output current information such as that shown in FIG. 71. In contrast, according to the EMI analysis method of the present embodiment, an electric current, which would arise when a change occurs in a signal appearing at an input pin of a composite cell serving as an object, is registered in a library, through use of a peak value of the electric current and a time lag based on a change in an input signal. A logic simulator estimates an electric current, on the basis of the assumption that a peak value of an electric current includes the previously-described time lag in accordance with a change in a signal appearing at an input pin of a composite cell.

FIG. 72 shows the configuration of an EMI analysis method using the value of a peak current and the amount of electric current.

A system to be used with the EMI analysis method shown in FIG. 72 comprises circuit connection information storage means 9001; pattern-of-signal-change storage means 9002; element current storage means 9003 for storing the amount of electric current flowing in a circuit element; total current storage means 9004 for storing a total amount of electric current flowing through the circuit element; and total current calculation means 9005 for calculating the total amount of electric current flowing through a circuit element.

Next will be described individual elements constituting the EMI analysis method shown in FIG. 72 and procedures for calculating the total amount of electric current shown in FIG. 74, from the circuit connection information shown in FIG. 73, the pattern of signal change shown in FIG. 69, and the amount of electric current flowing through a circuit element shown in FIG. 74.

The circuit connection information storage means 9001 stores information concerning the connection of a circuit to be analyzed, in the same manner as described in connection with the background art. Circuit connection information, such as that shown in FIG. 73, is

stored in advance in the circuit connection information storage means 9001. The pattern-of-signal-change storage 9002 stores the pattern of signal change to be applied to the circuit connection information, as in the case of a conventional pattern of signal change described in connection with the background art. As shown in FIG. 69, a pattern of change in a signal input to an input port CK and a pattern of change in a signal input to an input port D, such as those shown in FIG. 73, are stored in the pattern-of-signal-change storage 9002 beforehand.

The element current storage means 9003 stores, for each circuit element and in a form such as that shown in FIG. 75, pins 9301 in which electric current arises in an element after a change has arisen in an external input terminal of each element, time intervals 9302 (i.e., the time which elapses after a change has arisen in an external input terminal), total electric current 9303, and peak values 9304. Reference numeral 9305 designates flow of an electric current in an ANDOR circuit shown in FIG. 108; specifically, a total amount of 1 mA including a peak current of 0.5 mA flows into the circuit element after lapse of 1 ns from when input A has arisen. After lapse of 2 ns from when the input A has changed, a total mount of 3 mA including a peak value of 1.5 mH flows into the circuit element. Reference numeral 9306 designates flow

of an electric current in a circuit element shown in FIG. 108; namely, a total amount of 1 mA including a peak current of 0.5 mA flows after lapse of 1 ns from when input B has changed. Further, after lapse of 2 ns from when the input B has changed, an electric current of 3 ma including a peak value of 1.5 ma flows into the circuit. Reference numeral 9307 designates flow of an electric current in a circuit element shown in FIG. 108; specifically, a total amount of 3 mA including a peak value of 1.5 mA flows into the circuit element after lapse of 2 ns from when input C has changed.

The total current calculation means 9005 operates according to a flowchart such as that shown in FIG. 76. According to the flowchart shown in FIG. 76 concerning a method of calculating an electric current, processing pertaining to step 1504 of the conventional method of calculating an electric current is replaced by processing (pertaining to step 9404) in which an electric current is calculated while a rectangular waveform of the electric current is assumed on the basis of the total amount of electric current and a peak value with a time interval provided between information pieces concerning the amount of current of an element, the information having been stored in the element current storage means in association with a change in an input signal. In step 9401 is read

circuit connection information shown in FIG. 73 stored in the circuit connection information storage means 9001. In step 9402 is read a pattern of signal change, which is shown in FIG. 69 and is stored in the pattern-of-change-in-signal storage means 9002. In step 9403 is read element current information, which is shown in FIG. 75 and is stored in the element current information storage means 9003.

In step 9404, a pattern of signal change shown in FIG. 69 is imparted to the circuit connection information shown in FIG. 73 in step 9404, thereby enabling propagation of a signal. In a case where a change arises in a signal appearing at an external input terminal of a circuit element, which element is described in the information concerning the amount of electric current flowing an element, a rectangular waveform of an electric current is produced, by means of averaging the amount of electric current flowing through the external input terminal by means of a peak value. The thus-produced rectangular waveform is added to the information concerning the total mount of electric current obtained at a time which lags a predetermined period of time from the time a change has arisen in the external input terminal. After completion of propagation of a signal, in step 9405 the thus-calculated information concerning the total amount of

electric current obtained at each time shown in FIG. 74 is stored in the total current storage means 9004. As a result, there is produced a current waveform, such as that shown in FIG. 74, which is more realistic than that which is obtained by the conventional current calculation method and shown in FIG. 71.

(Eighteenth Embodiment)

An electromagnetic interference analysis method according to an eighteenth embodiment of the present invention will now be described.

Among operations related to EMI analysis, the present embodiment describes in particular extraction of a characteristic of EMI and calculation of the amount of an electric current, in the case where a circuit element is a register (signal holding) element synchronized with a clock signal. In a register element such as a flip-flop, an electric current flows at every rise or fall of a change which arises in a signal appearing at a clock pin. For example, a pattern of signal change shown in FIG. 78 is input to a circuit shown in FIG. 77, an electric current shown in FIG. 79 flows through the circuit. As in the case of the seventeenth embodiment, an electric current flows every time each of the logic elements constituting the circuit element is activated. A conventional tool for

analyzing power consumption on a gate level represents a signal change only when data are input to a flip flop; for example, at the time of a rise in a clock signal pin. For example, in a case where a pattern of signal change shown in FIG. 78 is input to the circuit shown in FIG. 77, the circuit outputs current information such as that shown in FIG. 80.

In the present embodiment, the timing at which an electric current flows through a flip-flop is determined by means of taking, as a reference, a rise and fall of a clock signal appearing at the flip-flop. Therefore, an electric current is estimated by means of taking, as a reference, a rise and fall of the clock signal. FIG. 72 shows the configuration of an EMI analysis method using the value of a peak current and the amount of electric current. A system to be used with the EMI analysis method shown in FIG. 72 comprises circuit connection information storage means 9001; pattern-of-signal-change storage means 9002; element current storage means 9003 for storing the amount of electric current flowing in a circuit element; total current storage means 9004 for storing a total amount of electric current flowing through the circuit element; and total current calculation means 9005 for calculating the total amount of electric current flowing through a circuit element.

[0203]

Next will be described individual elements constituting the EMI analysis method shown in FIG. 72 and procedures for calculating the total amount of electric current shown in FIG. 82, from the circuit connection information shown in FIG. 77, the pattern of signal change shown in FIG. 78, and the amount of electric current flowing through a circuit element shown in FIG. 81.

The circuit connection information storage means 9001 stores information concerning the connection of a circuit to be analyzed, in the same manner as described in connection with the background art. Circuit connection information, such as that shown in FIG. 77, is stored in advance in the circuit connection information storage means 9001.

[0205]

The pattern-of-signal-change storage 9002 stores the pattern of signal change to be applied to the circuit connection information, as in the case of a conventional pattern of signal change described in connection with the background art. As shown in FIG. 78, a pattern of change in a signal input to an input port CK and a pattern of change in a signal input to an input port D, such as those shown in FIG. 77, are stored in the pattern-of-signal-change storage 9002 beforehand.

The element current storage means 9003 stores, for each circuit element and in a form such as that shown in FIG. 81, information 9901 concerning the total amount of electric current flowing in a circuit element at a rise and fall of a clock signal and information 9902 about a peak value of the electric current flowing at a rise and fall of the clock signal.

The total current calculation means 9005 operates according to a flowchart, such as that shown in FIG. 83. According to the flowchart relating to a method of calculating an electric current shown in FIG. 83, processing pertaining to step 1504 of the conventional current calculation method is replaced by processing of calculating a rectangular waveform of the electric current from a peak value and a total amount of electric current flowing at a rise and fall of a clock signal (step 10104).

In step 10101, there is read the circuit connection information which is shown in FIG. 77 and stored in the circuit connection information storage means 9001. In step 10102, there is read a pattern of signal change which is shown in FIG. 78 and is stored in the pattern-of-signal-change storage 9002.

In step 10103, there is read the element current information which is shown in FIG. 114 and stored in the element current storage means 9003. In step 10104, the

pattern of signal shown in FIG. 78 is imparted to the circuit connection information shown in FIG. 77, thereby enabling propagation of a signal. In a case where a change arises in a signal appearing at an external input terminal of a circuit element, which element is described in the information concerning the amount of electric current flowing an element, a rectangular waveform of an electric current is produced by means of averaging an electric current corresponding to the electric current flowing through the external input terminal at a rise and fall of the signal by means of a peak value. The thus-produced rectangular waveforms are added to the information concerning the total mount of electric current obtained at a time when the change has arisen in the signal appearing at the external input terminal.

After completion of propagation of a signal, in step 10105 the thus-calculated information concerning the total amount of electric current obtained at each time shown in FIG. 82 is stored in the total current storage means 9004. As a result, there is produced a current waveform, such as that shown in FIG. 82, which is more realistic than that obtained by the conventional current calculation method and shown in FIG. 80.

(Nineteenth Embodiment)

An electromagnetic interference analysis method

according to a nineteenth embodiment of the present invention will now be described.

Conventional gate-level power consumption analysis means can change total electric current according to the value of a signal input to a logic element. More specifically, the conventional power consumption analysis means enables computation of so-called state-dependent power consumption. However, the conventional means cannot effect state-dependent power consumption including secular change in electric current and secular change in peak value.

Further, some conventional means determines a stationary value of another signal in the event of occurrence of a change in a certain signal. However, such means cannot determine a change in another signal. For instance, an electric current such as that shown in FIG. 86 (an electric current may change in amount according to whether a change arises in both terminals A and B simultaneously or in only terminal A), on the basis of the circuit connection information shown in FIG. 84 as well as a pattern of signal change shown in FIG. 85. In such a case, the conventional means can output only a waveform shown in FIG. 87.

In contrast, the EMI analysis method according to the present embodiment is characterized by holding secular

change in electric current and a peak value in the form of a state-dependent signal which takes into consideration changes in two or more signals. FIG. 72 shows the configuration of an embodiment of the EMI analysis method using the peak current and the amount of electric current, which are calculated in the fourteenth embodiment.

A system to be used with the EMI analysis method shown in FIG. 72 comprises circuit connection information storage means 9001; pattern-of-signal-change storage 9002; element current storage means 9003 for storing the amount of electric current flowing in a circuit element; total current storage means 9004 for storing a total amount of electric current flowing through the circuit element; and total current calculation means 9005 for calculating the total amount of electric current flowing through a circuit element.

Next will be described individual elements constituting the EMI analysis method shown in FIG. 72 and procedures for calculating the total amount of electric current shown in FIG. 90, from the circuit connection information shown in FIG. 84, the pattern of signal change shown in FIG. 85, and the amount of electric current flowing through a circuit element shown in FIG. 88.

The circuit connection information storage means 9001 stores information concerning the connection of a

circuit to be analyzed, in the same manner as described in connection with the background art. Circuit connection information, such as that shown in FIG. 84, is stored in advance in the circuit connection information storage means 9001.

The pattern-of-signal-change storage 9002 stores the pattern of signal change to be applied to the circuit connection information, as in the case of a conventional pattern of signal change described in connection with the background art. As shown in FIG. 85, a pattern of change in a signal input to an input port A and a pattern of change in a signal input to an input port B, such as those shown in FIG. 84, are stored in the pattern-of-signal-change storage 9002 beforehand.

The element current storage means 9003 stores, for each circuit element and in a form such as that shown in FIG. 88, a changed pin concerning an electric current which flows in a circuit element in the event of a change arising in the circuit element when a change occurs in an external terminal of the circuit element, a change arising in the logic status of another external pin under the influence of the change in the external terminal, total electric current, and information concerning a peak value.

For example, reference numeral 10601 designates a

circuit element: that is, a NAND circuit shown in FIG. 84, in which a total amount of 3 mA including a peak current of 1 mA flows into the circuit element, provided that an input signal A assumes a logic value of 1 and the logic value of an input signal B changes from 0 to 1 when a change arises in an output Y.

The total current calculation means 9005 operates according to a flowchart, such as that shown in FIG. 89. According to the flowchart relating to a method of calculating an electric current shown in FIG. 89, processing pertaining to step 1504 of the conventional current calculation method is replaced by processing of calculating a rectangular waveform of the electric current from total electric current and a peak value at the time of occurrence of a change in consideration of the status of another terminal (step 10704).

In step 10701, there is read the circuit connection information which is shown in FIG. 84 and stored in the circuit connection information storage means 9001. In step 10702, there is read a pattern of signal change which is shown in FIG. 85 and is stored in the pattern-of-signal-change storage 9002. In step 10703, there is read the element current information which is shown in FIG. 88 and stored in the element current storage means 9003.

In step 10704, the pattern of signal shown in FIG. 85 is imparted to the circuit connection information shown in FIG. 84, thereby enabling propagation of a signal. In a case where a change arises in a signal appearing at an external input terminal of a circuit element, which element is described in the information concerning the amount of electric current flowing in an element, a rectangular waveform of an electric current is produced by means of averaging the amount of electric current flowing through the external input terminal by means of a peak value in accordance with the status of another terminal. The thus-produced rectangular waveform is added to the information concerning the total mount of electric current obtained at a time when the change has arisen in the signal appearing at the external input terminal.

After completion of propagation of a signal, in step 10705 the thus-calculated information concerning the total amount of electric current obtained at each time shown in FIG. 90 is stored in the total current storage means 9004. As a result, there is produced a current waveform, such as that shown in FIG. 90, which is more realistic than that which is obtained by the conventional current calculation method and shown in FIG. 87.

(Twentieth Embodiment)

FIG. 91 is a block diagram showing the overall flowchart of an EMI analysis method according to the present embodiment. The EMI analysis method according to the present embodiment is identical with the EMI analysis method according to the seventh embodiment described in connection with FIG. 28, except for addition of a cell characterization section G2, replacement of the I-V table file A10 by an I-V table file (or an I-V function) G3, and replacement of the voltage drop calculation/instantaneously-changing current correction section A11 by a line voltage drop calculation/instantaneously-changing current correction section G4.

Reference symbol G2 denotes a cell characterization section for producing information unique to each cell; G3 denotes an I-V table file (or an I-V function) which represents, for each cell, the relationship between the amount of electric current and the degree of drop in line voltage; and G4 denotes a line voltage drop calculation/instantaneously-changing current correction section for calculating the degree of drop in line voltage and correcting the instantaneously-changing current calculated in step 11.

[0226]

The operation of the cell characterization section

G2 will now be described. The cell characterization section G2 receives a library 3 and calculates in advance the amount of electric current at the time of a change arising in a line voltage of each cell, thereby producing an I-V table file (or an I-V function) for each cell.

FIG. 92 is a block diagram showing the flow of processing of the voltage drop calculation/instantaneously-changing current correction section G4 according to the twentieth embodiment of the present invention. The function of the voltage drop calculation/instantaneously-changing current correction section G4 will now be described by reference to FIG. 92.

Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the seventh embodiment are assigned the same reference numerals, and their repeated explanations are omitted. Further, since the data 12 have already been described in detail in connection with the first embodiment, the same reference numeral is assigned to the data 12, and repeated explanation is omitted. In contrast with the voltage drop calculation/instantaneously-changing current correction section A11 employed in the seventh embodiment, the voltage drop calculation/instantaneously-changing current correction section G4 is configured such that the

current value correction section B12 is replaced by step H1.

There will now be described step H1. In step H1, there are entered the voltage drop information B11 prepared for each instance in step B10 according to the seventh embodiment and the I-V table file (or I-V function) which is produced for each cell by the cell characterization section G2 and represents the relationship between the amount of electric current and the degree of drop in line voltage. On the basis of a table file unique to each cell, the instantaneously-changing current information B1, which is produced on the basis of the instantaneously-changing current result 12 produced in step 11, is corrected. An instantaneously-changing current calculation result A6 is produced for each instance in consideration of a drop in line voltage which is dependent on the resistance of a power line.

As mentioned above, under the EMI analysis method according to the twentieth embodiment of the present invention, the relationship between the amount of electric current and the degree of drop in line voltage is characterized for each cell beforehand. In the seventh embodiment, EMI of a circuit element is analyzed on the basis of a uniform relationship between the amount of

electric current and the degree of drop in line voltage using the I-V table file (or I-V function). In contrast with the EMI analysis method of the seventh embodiment, the EMI analysis method of the present embodiment enables dependence of EMI on the structure (or layout) of a cell to be reflected in EMI analysis. Therefore, the EMI analysis method of the present embodiment can produce a more accurate model of a current waveform, thereby reducing undesired higher harmonic components included in the frequency characteristic of a circuit to be analyzed, the characteristic being determined by means of subjecting the current waveform to FFT processing.

Although the twentieth embodiment has described by reference to the first embodiment, the same result will be yielded even when the technical idea of the present embodiment is applied to any one of the fourteenth through nineteenth embodiments.

(Twenty-first Embodiment)

FIG. 93 is a block diagram showing the overall flowchart of an EMI analysis method according to a twenty-first embodiment of the present invention. The EMI analysis method according to the present embodiment is identical with the EMI analysis method according to the eighth embodiment described in connection with FIG. 36, except for addition of a cell characterization section I1,

deletion of the C-V table file (or a C-V function) C1, replacement of the I-V table file A10 by an I-C-V table file (or an I-V function) I2, and replacement of the voltage drop calculation/instantaneously-changing current correction section C2 by a line voltage drop calculation/instantaneously-changing current correction section I3.

Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the first embodiment are assigned the same reference numerals, and their repeated explanations are omitted. Reference symbol I1 denotes a cell characterization section for producing information unique to each cell; I2 denotes an I-C-V table file (or an I-C-V function) which represents, for each cell, the relationship among the amount of electric current, the degree of drop in line voltage, and decoupling capacitance existing between a power line and ground; and I3 denotes a line voltage drop calculation/instantaneously-changing current correction section for calculating the degree of drop in line voltage and correcting the instantaneously-changing current calculation result 12 produced in step 11.

The operation of the cell characterization section I1 will now be described. The cell characterization

section I1 receives a library 3, changes a line voltage of each cell, and calculates in advance the amount of electric current at the time of changing of the line voltage in consideration of decoupling capacitance existing between a power and ground, thereby producing an I-C-V table file (or an I-C-V function) I2 for each cell.

FIG. 94 is a block diagram showing the flow of processing of the voltage drop calculation/instantaneously-changing current correction section I4 according to the twenty-first embodiment of the present invention. The function of the voltage drop calculation/instantaneously-changing current correction section I3 will now be described by reference to FIG. 94. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the eighth embodiment are assigned the same reference numerals, and their repeated explanations are omitted. Further, since the data 12 have already been described in detail in connection with the first embodiment, the same reference numeral is assigned to the data 12, and repeated explanation is omitted.

In contrast with the voltage drop calculation/instantaneously-changing current correction section C2 employed in the eighth embodiment, the voltage drop calculation/instantaneously-changing current

correction section I3 is configured such that the current value correction section B12 is replaced by step J1.

There will now be described step J1. In step J1, there are entered the voltage drop information B11 prepared for each instance in step B10 according to the eighth embodiment, the I-C-V table file (or I-C-V function) I2 which is produced for each cell by the cell characterization section I1 and represents the relationship between the amount of electric current and the degree of drop in line voltage, and the capacitance information D2 concerning a capacitor provided in a segment interconnecting a power and ground, the information being prepared in step D1 in the eight embodiment. On the basis of a table file unique to each cell, the instantaneously-changing current information B1, which is produced on the basis of the instantaneously-changing current result 12 produced in step 11, is corrected. An instantaneously-changing current calculation result A6 is produced for each instance, in consideration of fluctuations in line voltage which are dependent on decoupling capacitance as well as the resistance of a power line.

As mentioned above, under the EMI analysis method according to the twenty-first embodiment of the present invention, the relationship among the amount of electric

current, the degree of drop in line voltage, and decoupling capacitance existing between a power and ground is characterized for each cell beforehand. In the eighth embodiment, EMI of a circuit element is analyzed on the basis of a uniform relationship between the amount of electric current, the degree of drop in line voltage, and decoupling capacitance existing between a power and ground, using the I-V table file (or I-V function) A10 and the C-V table (or C-V function) C1. In contrast with the EMI analysis method of the eighth embodiment, the EMI analysis method of the present embodiment enables dependence of EMI on the structure (or layout) of a cell to be reflected in EMI analysis. Therefore, the EMI analysis method of the present embodiment can produce a more accurate model of a current waveform, thereby reducing undesired higher harmonic components included in the frequency characteristic of a circuit to be analyzed, the characteristic being determined by means of subjecting the current waveform to FFT processing.

Although the twenty-first embodiment has described by reference to the first embodiment, the same result will be yielded even when the technical idea of the present embodiment is applied to any one of the fourteenth through nineteenth embodiments.

(Twenty-second Embodiment)

FIG. 95 is a block diagram showing the overall flowchart of an EMI analysis method according to a twenty-second embodiment of the present invention. The EMI analysis method according to the present embodiment is identical with the EMI analysis method according to the seventh embodiment described in connection with FIG. 28, except for addition of a comparison-and-determination section K1. Those portions of the EMI analysis method according to the present embodiment which are identical with those of the EMI analysis method according to the first embodiment are assigned the same reference numerals, and their repeated explanations are omitted. Reference symbol K1 denotes a comparison-and-determination section for determining whether or not the instantaneously-changing current calculation result A6—which takes into consideration a drop in line voltage produced by the voltage drop calculation/instantaneously-changing current correction section A11—becomes equal to an input to the next processing step.

Next will be described the operation of the comparison-and-determination section K1. The EMI analysis method according to the present embodiment is characterized by means of iterating the following operations; that is, re-entry, into the voltage drop calculation/instantaneously-changing current correction

section A11, of the instantaneously-changing current calculation result A6 which takes into consideration a drop in line voltage produced by the voltage drop calculation/instantaneously-changing current correction section A11, thereby producing another instantaneously-changing current calculation result A6 which newly takes into consideration a drop in line voltage.

The comparison-and-determination section K1 determines, through comparison, whether or not the number of times the foregoing operations has been iterated has reached a predetermined number of times. If a truth-value TRUE is yielded as a result of comparison, iteration of the operations is completed, and there is performed processing pertaining to the next step; that is, the operation of the FFT processing section 9, is performed.

As mentioned above, under the EMI analysis method according to the twenty-second embodiment of the present invention, the instantaneously-changing electric current result which has been corrected and calculated in consideration of the influence of fluctuations in line voltage is fed back, to thereby iterate voltage drop calculation/instantaneously-changing current correction operations. Accordingly, variation in the amount of electric current, which would otherwise be caused by a drop

in line voltage, can be made stable. Therefore, the EMI analysis method of the present embodiment can produce a more accurate model of a current waveform, thereby reducing undesired higher harmonic components included in the frequency characteristic of a circuit to be analyzed, the characteristic being determined by means of subjecting the current waveform to FFT processing.

In the present embodiment, the comparison-and-determination section K1 controls iteration of processing operations by means of determining whether or not a predetermined number of times has been reached. Alternatively, there may be employed a storage device for temporarily storing the instantaneously-changing current calculation result A6 which takes into consideration a drop in line voltage produced by the voltage drop calculation/instantaneously-changing current correction section A11. The instantaneously-changing current calculation result A6 stored in the storage device is entered again into the voltage drop calculation/instantaneously-changing current correction section A11, to thereby newly produce another instantaneously-changing current calculation result A6. Comparison is made between the thus-produced another instantaneously-changing current calculation result A6 and the instantaneously-changing current calculation

result A6 stored in the storage device. The foregoing operations are iterated until a difference falls within a predetermined range of allowance.

Although the twenty-second embodiment has been described with reference to the seventh embodiment, the same result will be yielded even when the technical idea of the present embodiment is applied to any one of the eighth, ninth, twentieth, and twenty-first embodiments.

(Twenty-third Embodiment)

An EMI analysis method according to a tenth embodiment of the present invention will now be described. In the fourteenth through twenty-second embodiments, an instantaneously-changing current of each cell is calculated from event information concerning each cell, the information being output from a logic simulator, by means of characterizing a peak current of a cell according to the type of cell and the amount of instantaneously-changing current for each event. The thus-calculated instantaneously-changing current is modeled as a rectangular waveform such that a peak value becomes equal to a peak current of the cell, thereby determining change in electric current. However, so long as the waveform of an instantaneous electric current is modeled as a triangular wave, a more realistic change in electric

current can be determined.

By way of example, there will now be described an EMI analysis method comprising the steps of:

modeling an instantaneously-changing electric current as a triangular wave whose height becomes equal to a characterized peak current, the width of the triangular wave being calculated such that the instantaneously-changing current becomes equal to the width of the triangular wave, to thereby calculate a more realistic change in electric current; and

subjecting the result of calculation of an electric waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

FIG. 96 shows an instantaneous electric current and a modeled triangular wave according to the present embodiment. In the drawing, "i" denotes an instantaneously-changing current; and "t" denotes a current processing time. Further, "h" denotes the height of a triangular wave serving as a model of an instantaneously-changing current. The height of a triangular waveform is extracted from a library in which the heights of triangular waveforms of cells are characterized. Reference symbol "w" denotes the width of

a triangular waveform and is calculated on the basis of "i" and "h." An electric current at time t+x is expressed by Eq.5 described previously. Further, an electric current at time t-x is also expressed by Eq.5.

The overall flow of processing of the EMI analysis method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 97 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the

instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment. Reference numeral 130 designates a peak current library including peak currents of cells. Reference numeral 160 denotes a triangular waveform height calculation section for calculating the height of a triangular wave from the peak current library 130. Reference numeral 161 designates a triangular waveform width calculation section for calculating the width of a triangular waveform from the height extracted by the triangular waveform height calculation section 160 and the instantaneously-changing current, such that the area of a triangular wave becomes equal to an instantaneously-changing current. Reference numeral 162 denotes a triangular-waveform-shaping section for modeling the instantaneously-changing current result 12 as a triangular wave having a constant width, the height of the triangular waveform corresponding to the peak value of the triangular waveform calculated by the rectangular waveform height calculation section 160, and the width of the rectangular waveform corresponding to the width calculated by the rectangular waveform width calculation

section 161.

FIG. 98 is a flowchart of processing pertaining to the triangular-waveform-shaping section 162, including processing pertaining to the triangular waveform height calculation section 160 and processing pertaining to the triangular waveform width calculation section 161. First, the peak current library 130 is read (step 1160). The following processing is iterated on a per-event basis until calculation of a current waveform is completed (step 1161). From the peak current library 130, a peak current of an instance which is an object of EMI analysis is extracted, and the thus-extracted peak current is taken as the height "h" of a triangular waveform (step 1162). This processing corresponds to processing of the triangular waveform height calculation section 160. Provided that "w" is taken as the width of a triangular waveform, the area of a triangular wave is Wxh/2 and is equal to the instantaneously-changing current of a cell of the event. Therefore, the width "w" of a triangular waveform is calculated from 2xi/h (step 1163). Reference symbol "i" denotes an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. This processing corresponds to processing pertaining to the triangular waveform width calculation section 161. Until variable "x" changes from 0 to W/2, h(c, i) expressed

by Eq.5 is added to I(t+x) and I(t-x). Further, Δt is added to variable "x" (steps 1164 and 1165). Here, I(t+x) denotes total electric current flowing through all the cells at time t+x, and I(t-x) denotes total electric current flowing through all the cells at time t-x. This processing corresponds to processing pertaining to the triangular-waveform-shaping section 162.

The current wave calculation result 8 can be obtained by means of the flow of a triangular waveform height calculation operation, a triangular waveform width calculation operation, and a triangular-waveform-shaping operation. The FFT processing section 9 subjects the current waveform calculation result 8 to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Twenty-fourth Embodiment)

An EMI analysis method according to a twenty-fourth embodiment of the present invention will now be described. In the fourteenth through twenty-second embodiments, an instantaneously-changing current of each cell is calculated from event information concerning each cell, the information being output from a logic simulator, by

means of characterizing a peak current of a cell according to the type of cell and the amount of instantaneously-changing current for each event. The thus-calculated instantaneously-changing current is modeled as a rectangular waveform such that a peak value becomes equal to a peak current of the cell, thereby determining change in electric current. However, so long as the waveform of an instantaneous electric current is modeled as a Gauss function wave, a more realistic change in electric current can be determined. By way of example, there will now be described an EMI analysis method comprising the steps of:

modeling an instantaneously-changing electric current as a multi-order-function waveform whose height becomes equal to a characterized peak current, the width of the multi-order-function wave being calculated such that the instantaneously-changing current becomes equal thereto, to thereby calculate a more realistic change in electric current; and

subjecting the result of calculation of an electric waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

FIG. 99 shows an instantaneous electric current and a modeled multi-order-function according to the present

embodiment. In the drawing, "i" denotes an instantaneously-changing current; and "t" denotes a current processing time. Further, "h" denotes the height of a multi-order-function wave serving as a model of an instantaneously-changing current. The height of a triangular waveform is extracted from a library in which the heights of multi-order-function waveforms of cells are characterized. Reference symbol "1" denotes the width of a multi-order-function wave and is calculated on the basis of "h," which has been calculated previously, and "i." Provided that the width of the multi-order-function waveform is taken as 2xw, an electric current at time t+x is expressed by Eq.6. The area of the multi-order-function waveform is expressed by Eq.8. The area of the multi-order-function waveform is equal to the value of "i." Here, "a" is expressed by Eq.9. Since the height "h" of a multi-order-function waveform is determined by Eq.6 when x=0, the height "h" is expressed by Eq.7. From Eq.7 and Eq.9, the width "w" is expressed by Eq.14 provided below.

$$w = \frac{15 \times i}{16 \times h} \quad \cdots \quad (14)$$

The overall flow of processing of the EMI analysis method according to the present embodiment is represented

by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 100 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment.

Reference numeral 130 designates a peak current library including peak currents of cells which are characterized according to the type of cell. Reference numeral 170 denotes a multi-order-function waveform height calculation section for calculating the height of a multi-order-function waveform from the peak current library 130. Reference numeral 171 designates a multi-order-function waveform width calculation section for calculating the width of a multi-order-function waveform from the height extracted by the multi-order-function waveform height calculation section 170 and the instantaneously-changing current, such that the area of a multi-order-function waveform becomes equal to an instantaneously-changing current. Reference numeral 172 denotes a multi-order-function waveform-shaping section for modeling the instantaneously-changing current result 12 into a multi-order-function waveform having a constant width, the height of the multi-order-function waveform corresponding to the peak value of the multi-order-function waveform calculated by the multi-order-function waveform height calculation section 170, and the width of the multi-order-function waveform corresponding to the width calculated by the multi-order-function waveform width calculation section 171.

FIG. 101 is a flowchart of processing pertaining to the multi-order-function waveform-shaping section 172, including processing pertaining to the multi-order-function waveform height calculation section 170 and processing pertaining to the multi-order-function waveform width calculation section 171. First, the peak current library 130 is read (step 1170). The following processing is iterated on a per-event basis until calculation of a current waveform is completed (step 1171). From the peak current library 130, a peak current of an instance which is an object of EMI analysis is extracted, and the thus-extracted peak current is taken as the height "h" of a multi-order-function waveform (step 1172). This processing corresponds to processing of the multi-order-function waveform height calculation section 170. The width "w" of a multi-order-function waveform is calculated by Eq.14 (step 1173). Reference symbol "i" denotes an instantaneously-changing current of a cell of an event, the event being an object of EMI analysis. This processing corresponds to processing pertaining to the multi-order-function waveform width calculation section 171. Until variable "x" changes from -w to w, "y" expressed by Eq.6 is added to I(t+x) and I(t-x). Further, Δt is added to variable "x" (steps 1174 and 1175). Here,

I(t+x) denotes total electric current flowing through all the cells at time t+x, and I(t-x) denotes total electric current flowing through all the cells at time t-x. This processing corresponds to processing pertaining to the multi-order-function waveform-shaping section 172.

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The current wave calculation result 8 can be obtained by means of the flow of a multi-order-function waveform height calculation operation, a multi-order-function waveform width calculation operation, and a multi-order-function waveform-shaping operation. The FFT processing section 9 subjects the current waveform calculation result 8 to an FFT operation, to thereby determine the frequency characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Twenty-fifth Embodiment)

An EMI analysis method according to a twenty-fifth embodiment of the present invention will now be described. In the fourteenth through twenty-second embodiments, an instantaneously-changing current of each cell is calculated from event information concerning each cell, the information being output from a logic simulator, by means of characterizing a peak current of a cell according

to the type of cell and the amount of instantaneously-changing current for each event. The thus-calculated instantaneously-changing current is modeled as a rectangular waveform such that a peak value becomes equal to a peak current of the cell, thereby determining change in electric current. However, so long as the waveform of an instantaneous electric current is modeled as a Gauss function waveform, a more realistic change in electric current can be determined.

By way of example, there will now be described an EMI analysis method comprising the steps of:

modeling, for each type of cell, an instantaneously-changing electric current as a Gauss function waveform whose height and width are characterized, to thereby calculate a more realistic change in electric current; and

subjecting the result of calculation of an electric waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

FIG. 50 shows an instantaneous electric current and a modeled Gauss function according to the present embodiment. In the drawing, "i" denotes an instantaneously-changing current; "t" denotes a current

processing time; and "h" denotes the height of a Gauss function wave serving as a model. The height "h" is equal to a peak current characterized according to the type of cell. Reference symbol "w" denotes a width of a Gauss function serving a model, and the width "w" corresponds to a value characterized according to the type of cell. In the present embodiment, a Gauss function serving as a model is expressed as Eq.11. This function is called a Gaussian function. Let x=0, Eq.11 provides "h," which represents the height of a Gaussian function waveform. From Eq.11, let x=3xW, there is derived a value of 0.0001xh (i.e., 0.01% of the height of a Gaussian function wave). This value is taken as a limit on the width of a Gaussian function serving as a model, and the width of the Gaussian function is taken as "6xw."

The overall flow of processing of the EMI analysis method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 102 is a detailed block diagram showing the current waveform calculation section 7 according to the present embodiment. Reference numeral 11 designates an instantaneously-changing current calculation section for calculating a momentary change in the current of each cell

from the event information 5 concerning each cell, the information being output from the logic simulator 4. Calculation of momentary change in current is technically analogous to calculation of power consumption through a conventional logic simulation. Reference numeral 12 designates a calculation result of an instantaneously-changing current (hereinafter referred to as an "instantaneously-changing current calculation result 12") determined by the instantaneously-changing current calculation section 11. FIG. 3 shows an example instantaneously-changing current calculation result 12. As can be seen from FIG. 3, according to the instantaneously-changing current calculation result, the waveform of an electric current assumes a δ function. Therefore, an EMI component cannot be analyzed through an FFT operation. Thus far, the processing has been identical with the current wave calculation operation of the first embodiment. A Gaussian function waveform height calculation section 180 extracts a peak value of a Gaussian function serving as a model, from the peak current library 130 including peak currents of cells characterized according to the type of cell. Reference numeral 181 designates a wave width library includes wave widths of cells characterized according to the type of cell. Reference numeral 182 designates a Gaussian function

waveform width calculation section for extracting, from the wave width library 181, the width of a Gaussian function waveform serving as a model.

Reference numeral 183 designates a Gaussian function waveform-shaping section for modeling the instantaneously-changing current result 12 as a Gaussian function wave having a peak value calculated by the Gaussian function waveform height calculation section 180 and a width calculated by the Gaussian function waveform width calculation section 182.

FIG. 103 shows the flowchart of processing pertaining to the Gaussian function waveform-shaping section 183, including processing pertaining to the Gaussian function waveform height calculation section 180 and processing pertaining to the Gaussian function waveform width calculation section 182. First, the peak current library 130 is read (step 1180), and the wave width library 181 is read (step 1181).

The processing provided below is iterated on a per-event basis until calculation of a current waveform is completed (step 1182). From the peak current library 130, a peak current of an instance which is an object of

EMI analysis is extracted, and the thus-extracted peak current is taken as the height "h" of a Gaussian function waveform (step 1183). This processing corresponds to processing of the Gaussian function waveform height calculation section 180. The width "w" of a Gaussian function waveform which is an object of EMI analysis is extracted from the wave width library 181, and the thus-extracted width is taken as the width "w" of a Gaussian function waveform (step 1184). This processing corresponds to processing of the Gaussian function waveform width calculation section 182. Until variable "x" changes from -3xw to 3xw, "y" expressed by Eq.11 is added to I(t+x). Further, Δt is added to variable "x" (steps 1185 and 1186). Here, I(t+x) denotes total electric current flowing through all the cells at time t+x. This processing corresponds to processing pertaining to the Gaussian function waveform-shaping section 183.

The current wave calculation result 8 can be obtained by means of the flow of a Gaussian function waveform height calculation operation, a Gaussian function waveform width calculation operation, and a Gaussian function waveform-shaping operation. The FFT processing section 9 subjects the current waveform calculation result 8 to an FFT operation, to thereby determine the frequency

characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

(Twenty-sixth Embodiment)

An EMI analysis method according to a twenty-sixth embodiment of the present invention will now be described.

The EMI analysis method according to the present embodiment is characterized by modeling an instantaneously-changing current while the information concerning a current waveform of each circuit element (or cell) which is described in connection with the fourteenth through twenty-second embodiments is separated into an element dependent on a short circuit current (also called "short circuit-current-dependent element") and another element dependent on a charge current (also called "charge-current-dependent element"). In contrast with the thirteenth embodiment, the present embodiment effects modeling of each of the circuit elements (cells), thereby enabling formation of a more accurate model of electric current.

For example, in a case where the circuit connection information shown in FIG. 110 and the pattern of signal change shown in FIG. 12 are imparted to a circuit element, an electric current shown in FIG. 104 flows through the

circuit element. In such a case, the conventional EMI analysis method enables formation of only a waveform such as that shown in FIG. 14. Even in the case of the thirteenth embodiment, there is produced only a waveform such as that shown in FIG. 58. In contrast, the EMI analysis method according to the present embodiment enables formation of a more correct electric current. FIG. 72 shows the configuration of an EMI analysis method according to the present embodiment, the method using the value of a peak current and the amount of electric current described in connection with the fourteenth embodiment.

A system to be used with the EMI analysis method shown in FIG. 72 comprises circuit connection information storage means 9001; pattern-of-signal-change storage 9002; element current storage means 9003 for storing the amount of electric current flowing in a circuit element; total current storage means 9004 for storing a total amount of electric current flowing through the circuit element; and total current calculation means 9005 for calculating the total amount of electric current flowing through a circuit element.

Next will be described individual elements constituting the EMI analysis method shown in FIG. 72 and

procedures for calculating the total amount of electric current shown in FIG. 106, from the circuit connection information shown in FIG. 110, the pattern of signal change shown in FIG. 12, and the amount of electric current flowing through a circuit element shown in FIG. 105.

The circuit connection information storage means 9001 stores information concerning the connection of a circuit to be analyzed in the same manner as described in connection with the background art. Circuit connection information, such as that shown in FIG. 110, is stored in advance in the circuit connection information storage means 9001.

The pattern-of-signal-change storage 9002 stores the pattern of signal change to be applied to the circuit connection information, as in the case of a conventional pattern of signal change described in connection with the background art. As shown in FIG. 111, a pattern of change in a signal input to an input port CK and a pattern of change in a signal input to an input port D, such as those shown in FIG. 110, are stored in the pattern-of-signal-change storage 9002 beforehand.

The element current storage means 9003 stores for

each circuit element and in a form such as that shown in FIG. 105, the total amount of electric current flowing in a circuit element (cell), a peak value of the electric current, the total amount of charge current, and a peak current.

The total current calculation means 9005 operates according to a flowchart, such as that shown in FIG. 107. According to the flowchart relating to a method of calculating an electric current shown in FIG. 107, processing pertaining to step 1504 of the conventional current calculation method is replaced by processing of calculating a rectangular waveform of the short circuit current from a peak value and the total amount of electric current, calculating a rectangular waveform of the charge current from a peak value and the total amount of electric current, and merging the thus-calculated rectangular waveforms into a single rectangular waveform (step 12504). In step 12501, there is read the circuit connection information which is stored in the circuit connection information storage means 9001 and shown in FIG. 110.

In step 12502, there is read a pattern of signal change which is shown in FIG. 111 and is stored in the pattern-of-signal-change storage 9002. In step 12503,

there is read the element current information which is shown in FIG. 105 and stored in the element current storage means 9003. In step 12504, the pattern of signal shown in FIG. 111 is imparted to the circuit connection information shown in FIG. 110, thereby enabling propagation of a signal. In a case where a change arises in a signal appearing at an external input terminal of a circuit element, which element is described in the information concerning the amount of electric current flowing in an element, a rectangular waveform of an electric current is produced by means of averaging a short circuit current component of the electric current by a peak value of the short circuit current component, and a rectangular waveform of an electric current is produced by means of averaging a charge current component of the electric current by a peak value of the charge current component. The thus-formed rectangular waveforms are added to the information concerning the total mount of electric current obtained at a time when the change has arisen in the signal appearing at the external input terminal. After completion of propagation of a signal, in step 12505 the thus-calculated information concerning the total amount of electric current obtained at each time shown in FIG. 106 is stored in the total current storage means 9004. As a result, there is produced a current

waveform, such as that shown in FIG. 106, which is more realistic than that which is obtained by the conventional current calculation method and shown in FIG. 14.

(Twenty-seventh Embodiment)

Next will be described an EMI analysis method according to a twenty-seventh embodiment of the present invention. The tenth embodiment has described that a more realistic change in current can be materialized by means of calculating an instantaneously-changing current of each cell from event information concerning the cell, the information being output from a logic simulator, and modeling the thus-calculated instantaneously-changing current as a triangular wave. The EMI analysis method according to the present embodiment is characterized by calculating a current waveform in consideration of output slew information; that is, the time which elapses from the time a change arises in a signal appearing at an output terminal of a cell until the change has been canceled.

By way of example, there will now be described an EMI analysis method comprising the steps of:

modeling an instantaneously-changing current as a triangular waveform by means of calculating the width of a triangular waveform for each event information in consideration of slew information concerning an output

terminal of a cell and the height of the triangular waveform on the basis of the thus-calculated width such that the area of the triangular waveform becomes equal to the amount of current of each event;

calculating a more realistic change in electric current by means of using an existing library in its present form; and

subjecting the result of calculation of an electric waveform to FFT processing, thereby determining the frequency characteristic of an EMI component of a circuit of interest.

FIG. 117 shows a logic value (see FIG. 117A) and a modeled triangular waveform (see FIG. 117B), which are to be used for executing the EMI analysis method according to the present embodiment. Reference symbol "t" denotes a current processing time, and "W" denotes the width of a triangular waveform serving as a model of an instantaneously-changing current. The width "W" is determined by means of calculating an instantaneously-changing current of each cell from event information of each cell, in consideration of output slew information. Further, "h" denotes the height of a triangular waveform and is calculated from "i" and "W." Here, h=2xI/W.

FIG. 118 shows the configuration of a system for

effecting the EMI analysis method according to the present invention. The system used for effecting the EMI analysis method shown in FIG. 118 comprises pattern-of-signal-change storage means 1171; element current storage means 1172 for storing the amount of electric current flowing in a circuit element; output slew information storage means 1173; and current waveform calculation means 1175 for calculating a current waveform on the basis of data output from the pattern-of-signal-change storage means 1171, the element current storage means 1172, the output slew information storage means 1173, and circuit connection information storage means 1174. The system outputs a calculation result of a current waveform 1176 (hereinafter referred to simply as a "current waveform calculation result 1176").

FIG. 119 is a flowchart of a triangular-waveform-shaping operation, including a triangular waveform height calculation operation and a triangular waveform width calculation operation. The following processing is iterated on a per-event basis after reading of an output slew (step 1190) until calculation of a current waveform is completed (step 1191). A base of the triangular waveform is extracted as an output slew while a point at which a change arises in an event is taken as

a center (step 1192). An isosceles triangle whose area is equal to the amount of electric current flowing through the event is taken as a current waveform of the event. The area of a triangular wave is Wxh/2 and assumes a value "i." The height "h" of a triangular wave is calculated from 2xi/W (step 1193). Reference symbol "i" denotes an instantaneously-changing current of a cell of an event which is an object of EMI analysis. This processing corresponds to processing pertaining to the triangular waveform height calculation section 100 according to the tenth embodiment. Until variable "x" changes from 0 to W/2, (2xh/W)•x+h is added to I(t+x) and I(t-x). Further, Δt is added to variable "x" (steps 1194, 1195, and 1196). Here, I(t+x) denotes total electric current flowing through all the cells at time t+x, and I(t-x) denotes total electric current flowing through all the cells at time t-x. This processing corresponds to processing pertaining to the triangular-waveform-shaping section 101.

The current wave calculation result 76 can be obtained by means of the flow of a triangular waveform height calculation operation and a triangular-waveform-shaping operation. The FFT processing section 9 subjects the current wave calculation result 76 to an FFT operation, to thereby determine the frequency

characteristic of an EMI component. As a result, there can be obtained an EMI analysis result 10.

The EMI analysis method enables estimation of an electric current with sufficient accuracy from only the information which is currently used by a power consumption analysis tool and used for verifying a delay.

(Twenty-eighth Embodiment)

Next will be described an EMI analysis method according to a twenty-eighth embodiment of the present invention. The EMI analysis method according to the present embodiment is characterized by means of calculating a current waveform, in consideration of whether an event is a rise or a fall and in addition to the feature of the EMI analysis method according to the twenty-seventh embodiment. FIG. 120 shows a logic value (see FIG. 120A) and a modeled triangular waveform (see FIG. 120B), which are to be used for effecting an EMI analysis method according to the present embodiment. Reference symbol "t" denotes a current processing time, and "W" denotes the width of a triangular waveform serving as a model of an instantaneously-changing current. The width "W" is determined by means of calculating an instantaneously-changing current of each cell from event

information of each cell, in consideration of output slew information. There is employed rise-dependent coefficient/fall-dependent coefficient storage means 1207, and current waveform calculation means 1205 calculates a current waveform in accordance with whether an event is a rise or a fall.

The overall flow of processing of the EMI analysis method according to the present embodiment is represented by the same block diagram as that employed in the first embodiment (see FIG. 1).

FIG. 121 shows the configuration of a system for effecting the EMI analysis method according to the present invention. The system used for effecting the EMI analysis method shown in FIG. 121 comprises pattern-of-signal-change storage means 1201; element current storage means 1202 for storing the amount of electric current flowing in a circuit element; output slew information storage means 1203; and current waveform calculation means 1205 for calculating a current waveform on the basis of data output from the pattern-of-signal-change storage means 1201, the element current storage means 1202, the output slew information storage means 1203, and circuit connection information storage means 1204. The system outputs a calculation result of a current waveform 1206

(hereinafter referred to simply as a "current waveform calculation result 1206").

In the present embodiment, a current waveform is calculated in consideration of whether an event is a rise or a fall, by reference to the rise/fall-dependent coefficient storage means 1207, in addition to the operations of the EMI analysis method described in connection with the twenty-seventh embodiment. A more realistic change in current is calculated by use of an existing library in its present form, and by subjecting a calculation result of a current wave to FFT processing, to thereby determine the frequency characteristic of an EMI component and enable EMI analysis.

(Twenty-ninth Embodiment)

Next will be described an EMI analysis method according to a twenty-ninth embodiment of the present invention. According to the present method, there is estimated the amount of electric current on the basis of event information, the number of cells determined according to a SPICE netlist provided in a cell, an output load capacitance, input slew information, the relationship between an input slew and the amount of current, and a time at which a change has arisen in an input

signal, or a delay time. Information concerning the amount of electric current which flows in a single event is calculated from an output load capacitance and a table representing the relationship between an input slew and the amount of electric current. FIG. 122 shows a logic value (see FIG. 122A) and a modeled triangular waveform (see FIG. 122B), which are to be used for effecting an EMI analysis method according to the present embodiment. Reference symbol "t_d" designates a delay time; "t" denotes a current processing time; and "W" denotes the width of a triangular waveform serving as a model of an instantaneously-changing current. The width "W" is determined by means of calculating an instantaneously-changing current of each cell from event information of each cell, on the basis of output slew information taking into consideration a delay time td caused by multistage connection. Here, there is calculated the amount of current independent of an output load (i.e., the amount of non-dependent current) beforehand, and the thus-calculated amount of current is stored. A base of the triangular waveform is taken as an output slew while a point at which a change arises in an output is taken as a center. Further, there are employed, as output loads, an angular waveform whose area is equal to the amount of non-dependent current or to the amount of current flowing

when

electric current-capacitance is 0 and a triangular waveforms equal in number to the number of cells within the delay time. As shown in FIG. 123, the EMI analysis method according to the present embodiment is provided with a load capacitance/slew-dependent element current information table 1226; element current calculation means 1227 for calculating the amount of electric current flowing through a cell from the load capacitance/slew-dependent element current information table 1226; and non-load element current storage means 1228 for storing the amount of electric current flowing through a non-load element calculated by the element current calculation means 1227. By use of these means, a current waveform is calculated. The systemwhich is shown in FIG. 123 and used for effecting the EMI analysis method according to the present invention, comprises the load capacitance/slew-dependent element current information table 1226; the element current calculation means 1227 for calculating the amount of electric current flowing through a cell from the load capacitance/slew-dependent element current information table 1226; the non-load element current storage means 1228 for storing the amount of electric current flowing through a non-load element calculated by the element current calculation means 1227;

pattern-of-signal-change storage means 1221; element current storage means 1222 for storing the amount of electric current flowing in a circuit element at the time of an event, the electric current being calculated by the element current calculation means 1227; output slew information storage means 1223; and current waveform calculation means 1225 for calculating a current waveform on the basis of data output from the pattern-of-signal-change storage means 1221, the element current storage means 1222, the output slew information storage means 1223, circuit connection information storage means 1224, number-of-stages storage means 1229 for storing the number of stages in a composite cell, and the non-load element current storage means 1228. The system outputs a calculation result of a current waveform 1206 (hereinafter referred to simply as a "current waveform calculation result 1206").

In the twenty-ninth embodiment, there are stored a plurality of triangular waveforms which are equal in number to cells, such that the total area of a triangular waveform becomes equal to the amount of electric current obtained when a capacitance assumes a value of 0, during a period of time from the time when a change has arisen in an input signal until a change arises in an event. A

more realistic change in current is calculated from an existing library in its present form, and the calculation result of current waveform is subjected to FFT processing, thereby determining the frequency characteristic of an EMI component arising in a circuit to be analyzed and enabling EMI analysis.

The present invention evaluates electromagnetic interference arising in an LSI through a simulation, by means of accurately analyzing a change in a power current, which change can be said to primarily account for electromagnetic interference. In order to solve the problem, a highly-accurate power current analysis function is added to a gate-level simulation, thereby preventing consumption of much time, which would otherwise be required by the conventional EMI analysis method using transistor-level current analysis.

What is claimed is:

1. An electromagnetic interference analysis method for analyzing the amount of electromagnetic interference arising in an LSI by means of performing a logic simulation, the method comprising:

an instantaneous current calculation step of calculating the amount of instantaneous electric current from event information, the information being produced when a change arises in a signal and including the instance name of each cell in which the change has arisen, the name of the signal, a time at which the change has arisen, and transition information;

a modeling step of modeling the instantaneous electric current according to a predetermined rule; and

an FFT processing step of subjecting to fast Fourier processing (hereinafter referred to as "FFT processing") the information concerning a change in electric current, the information being calculated through a modeling step.

2. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes an averaging step of averaging the instantaneous current over a certain discrete width, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being produced by the averaging step.

3. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a rectangular waveform modeling step of modeling the instantaneous current as a rectangular waveform whose height is calculated for information for each event such that the area of the rectangular waveform becomes equal to the amount of electric current of each event, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the rectangular waveform modeling step.

4. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a geometrically-similar rectangular waveform modeling step of modeling the instantaneous current as a geometrically-similar rectangular waveform whose height and width are calculated such that the area of the rectangular waveform becomes equal to the amount of electric current of each event, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the geometrically-similar rectangular waveform modeling step.

5. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes

a rectangular waveform modeling step of calculating the instantaneous electric current for each event information, and a step of modeling the instantaneous current as a rectangular waveform through use of the amount of electric current and a table representing the relationship between the width and height of a rectangular waveform, to thereby subject to FFT processing the information concerning a change in electric current calculated in the rectangular waveform modeling step.

6. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a step of calculating the instantaneous electric current for information for each event, and a rectangular waveform modeling step of modeling the instantaneous current as a rectangular waveform through use of a slew in input waveform and a table representing the relationship between the width and height of a rectangular waveform, to thereby subject to FFT processing the information concerning a change in electric current calculated in the rectangular waveform modeling step.

7. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a step of calculating the instantaneous electric current for information for each event, and a rectangular waveform modeling step of modeling the instantaneous current as a

rectangular waveform through use of an output load capacitance and a table representing the relationship between the width and height of a rectangular waveform, to thereby subject to FFT processing the information concerning a change in electric current calculated in the rectangular waveform modeling step.

8. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a step of calculating a drop in voltage from the amount of electric current flowing in each cell and the resistance of a power and correcting the amount of instantaneous electric current of each cell for each event, on the basis of the relationship between the drop in voltage and the amount of instantaneous electric current.

9. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a step of calculating a drop in voltage from the amount of electric current flowing in each cell, the resistance of a power line, and the capacitance of an on-chip capacitor, and correcting the amount of instantaneous electric current of each cell for each event, on the basis of the relationship between the drop in voltage and the amount of instantaneous electric current.

10. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step

includes a step of transiently analyzing a power RC of each cell and a cell power source, accurately calculating a drop in voltage, and a correction step of correcting the amount of instantaneous electric current of each cell for each event, on the basis of the relationship between the drop in voltage and the amount of instantaneous electric current.

11. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a triangular waveform modeling step of modeling the instantaneous current as a triangular waveform which has a given width and whose height is calculated for each event information such that the amount of instantaneous electric current becomes equal to the area of the triangular waveform, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the triangular waveform modeling step.

12. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a multi-order-function waveform modeling step of modeling the instantaneous current as a multi-order-function waveform, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being

calculated in the multi-order-function waveform modeling step.

13. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes an exponential function waveform modeling step of modeling the instantaneous current as an exponential-function waveform, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the exponential-function waveform modeling step.

14. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a step of modeling the amount of instantaneous electric current while separating the same into a short circuit electric current component and a charge current component.

15. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes a calculation step of calculating the height of a rectangular waveform from a library in which peak currents of cells are characterized according to the type of cell, and a rectangular waveform modeling step of modeling the amount of instantaneous electric current as a rectangular waveform, the peak current calculated in the

calculation step being taken as the height of the rectangular waveform and the area of the triangular waveform being equal to the amount of electric current of each event, and the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the rectangular waveform modeling step.

16. The electromagnetic interference analysis method as defined in claim 15, wherein the calculation step includes a step of calculating a peak current for each cell from information concerning a slew in the cell, by reference to a library in which the relationship between a slew in input waveform and a peak current is characterized in the form of a table according to the type of cell.

17. The electromagnetic interference analysis method as defined in claim 15, wherein the calculation step includes a step of calculating a peak current for each cell from information concerning a load capacitance of a cell, by reference to a library in which the relationship between a load capacitance and a peak current is characterized in the form of a table according to the type of cell.

18. The electromagnetic interference analysis method as defined in claim 15, wherein the calculation step includes a step of setting a plurality of peak currents

for a composite cell and calculating the heights of a plurality of rectangular waveforms through use of a characterized library, and the rectangular waveform modeling step corresponds to a step of modeling the amount of electric current into a plurality of rectangular waveforms.

19. The electromagnetic interference analysis method as defined in claim 15, wherein the calculation step includes a step of setting a plurality of peak currents for each of the rise and fall of a flip-flop (FF) cell and calculating the heights of a plurality of rectangular waveforms through use of a characterized library, and the rectangular waveform modeling step corresponds to a step of modeling the amount of electric current into a plurality of rectangular waveforms.

20. The electromagnetic interference analysis method as defined in claim 15 , wherein the calculation step includes a step of calculating the height of a rectangular waveform through use of a library in which peak currents are characterized, in consideration of the state of an input signal.

21. The electromagnetic interference analysis method as defined in claim 15, wherein the modeling step includes

a step of calculating a drop in voltage from the

amount of electric current determined according to the type of cell and from the resistance of a power line; and

a correction step of characterizing, for each cell, the relationship between a drop in voltage and the amount of instantaneous electric current in the form of a table, to thereby correct the amount of instantaneous electric current for each event of the cell.

22. The electromagnetic interference analysis method as defined in claim 15, wherein the modeling step includes

a step of calculating a drop in voltage from the amount of electric current determined according to the type of cell, the resistance of a power line, and the capacitance of an on-chip capacitor; and

a correction step of characterizing, for each cell, the relationship between a drop in voltage and the amount of instantaneous electric current in the form of a table, to thereby correct the amount of instantaneous electric current for each event of the cell.

23. The electromagnetic interference analysis method as defined in Claim 10, wherein the correction step includes a step of iterating several times calculation of a drop in voltage and correction of a current waveform.

24. The electromagnetic interference analysis method as defined in claim 15, wherein the calculation step

includes a step of modeling the amount of instantaneous electric current while separating the same into a short circuit electric current component and a charge current component.

25. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes

a triangular waveform modeling step of modeling the instantaneous current as a triangular waveform whose width is calculated for each event information in consideration of slew information (i.e., an output slew) for an output terminal of a cell for each event information such that the area of the triangular waveform becomes equal to the amount of electric current of each event, the height of the triangular waveform being calculated on the basis of the width, and

the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the triangular waveform modeling step.

26. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes

a triangular height calculation step of calculating the height of a triangular waveform such that the area of

the triangular waveform becomes equal to the amount of electric current of each event, by means of multiplying the amount of instantaneous electric current by a coefficient corresponding to the state of an event of a cell, in consideration of whether the event of the cell is in a rising state or a falling state.

27. The electromagnetic interference analysis method as defined in claim 1, wherein the modeling step includes

a step of calculating the amount of instantaneous electric current for each event information in the case of a composite cell; and

a triangular waveform modeling step of modeling the amount of instantaneous electric current as a plurality of triangular waveforms which are equal in number to the stages provided in the composite cell, through use of a table representing the relationship between the width and height of a triangular waveform; and

the FFT processing step includes a step of subjecting to FFT processing information concerning a change in current, the information being calculated in the triangular waveform modeling step.

28. An electromagnetic interference analysis system for analyzing the amount of electromagnetic interference arising in an LSI by means of performing a logic simulation,

the system comprising:

a logic simulator;

computation means which is connected to the logic simulator and calculates the amount of instantaneous electric current from event information, the information being produced when a change arises in a signal and including the instance name of each cell in which the change has arisen, the name of the signal, a time at which the change has arisen, and transition information;

modeling means for modeling the instantaneous electric current according to a predetermined rule; and

fast Fourier (FFT) conversion means for subjecting to fast Fourier processing the information concerning a change in electric current, the information being calculated through a modeling step , thereby analyzing the amount of electromagnetic interference arising in an LSI on the basis of a signal output from the FFT conversion means.

ABSTRACT

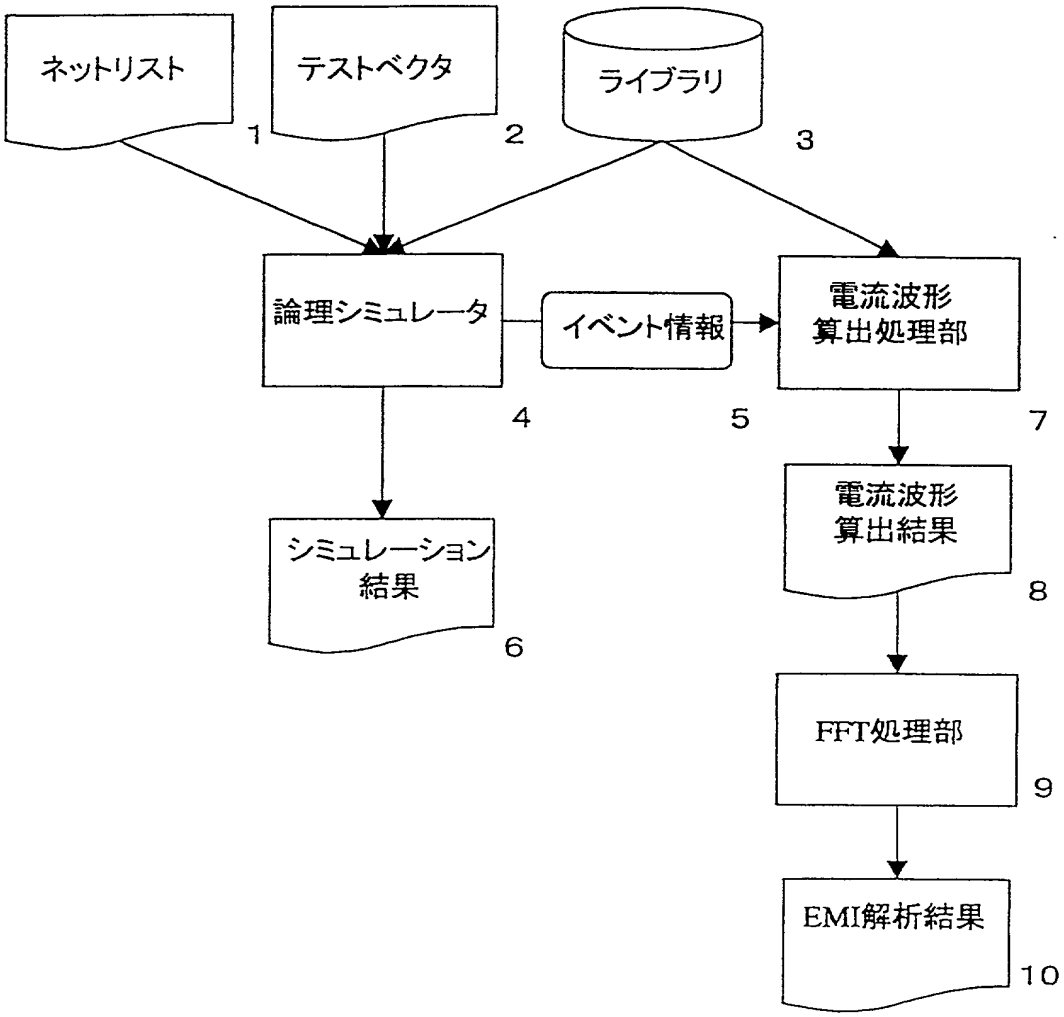
In a gate-level logic simulation, a change in electric current is calculated from event information 5 output from a logic simulator 4 through use of a current waveform calculation section 7. The thus-calculated change in current is subjected to FFT processing through use of an FFT processing section 9, thereby determining a frequency characteristic of EMI and enabling EMI analysis.

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【書類名】　　図面

Fig. 1

図1 全体ブロック図



09.05.'99 09:26 NO.0200 P.05

Fig. 2

図2電流波形算出処理
ブロック図(実施形態1)

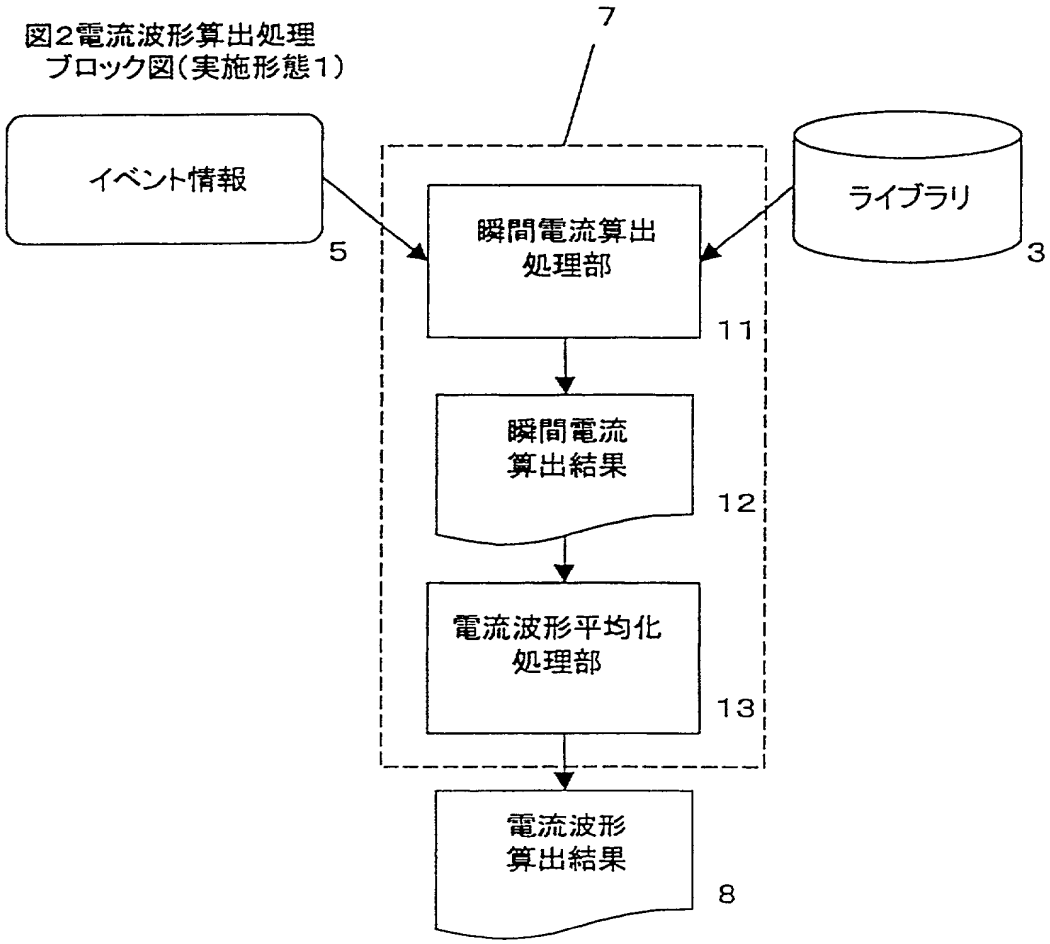


Fig. 3

図3 瞬間電流算出結果

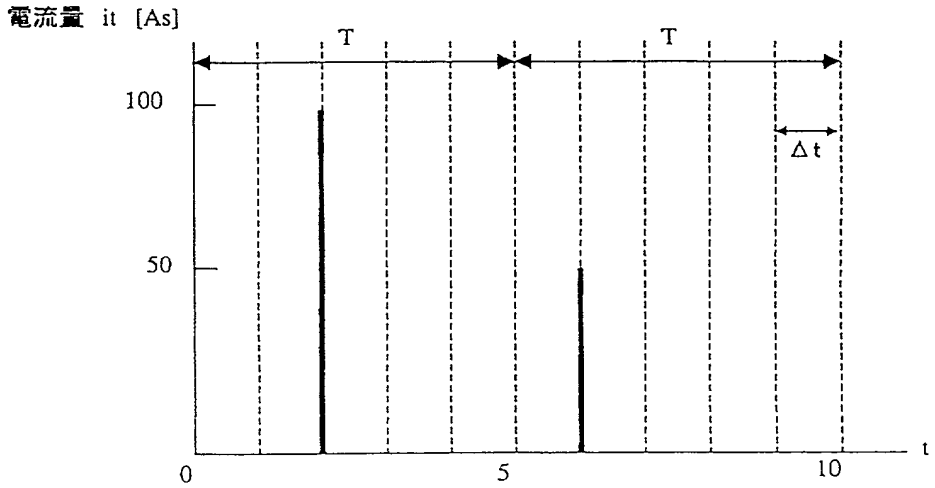
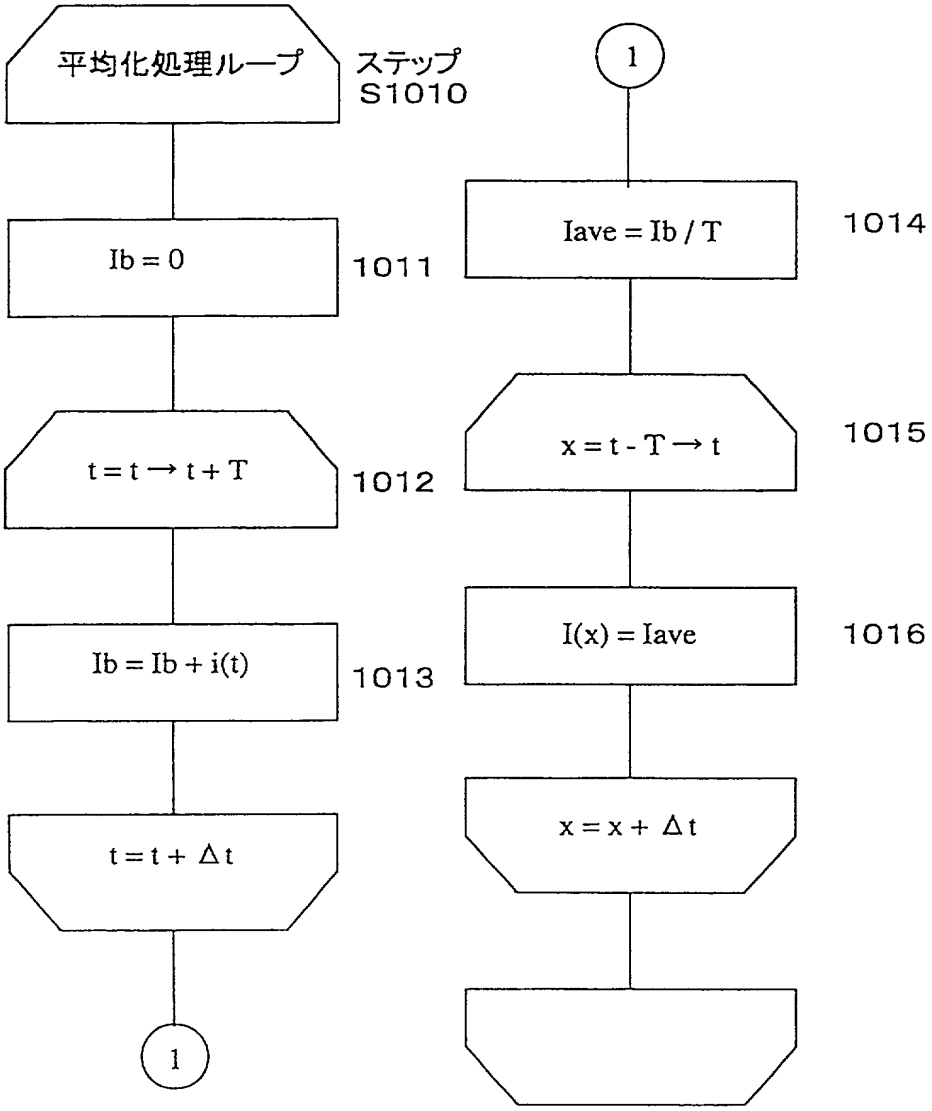


Fig. 4

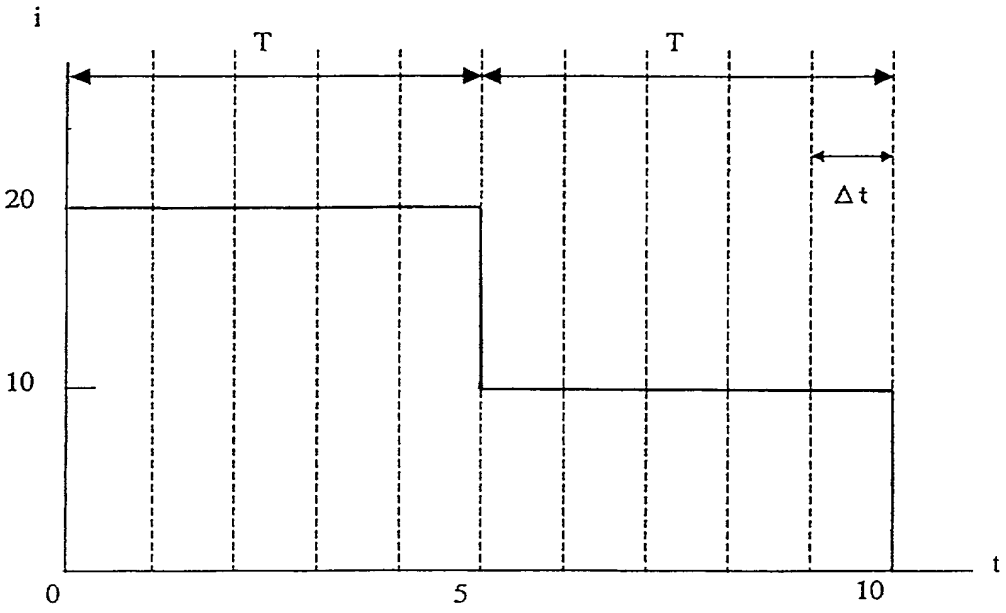
図4 電流波形平均化処理フロー図



0505382-030900

Fig. 5

図5 電流波形算出結果(実施形態1)



T＝5 の時

0376100330990705

Fig. 6

図6 FFT解析結果

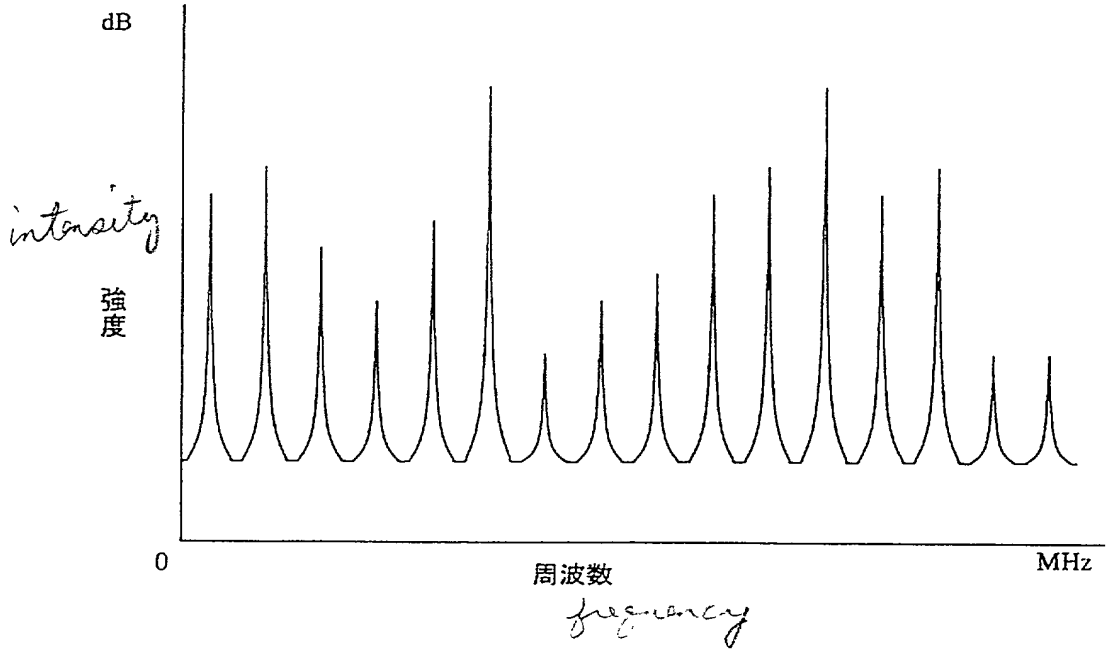


Fig. 7

図7 矩形波モデル(実施形態2)

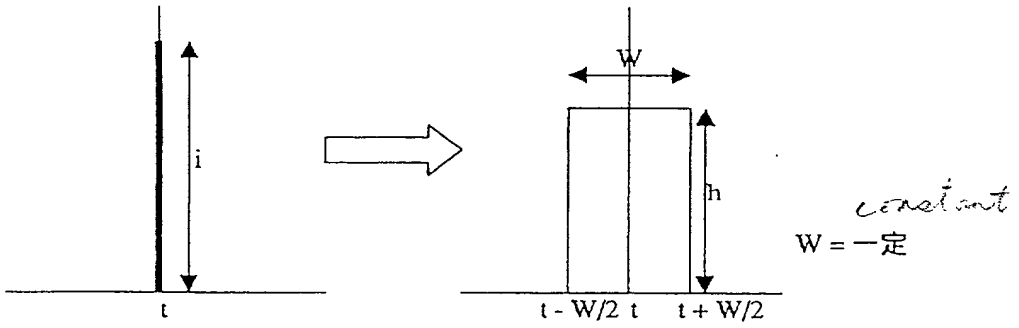
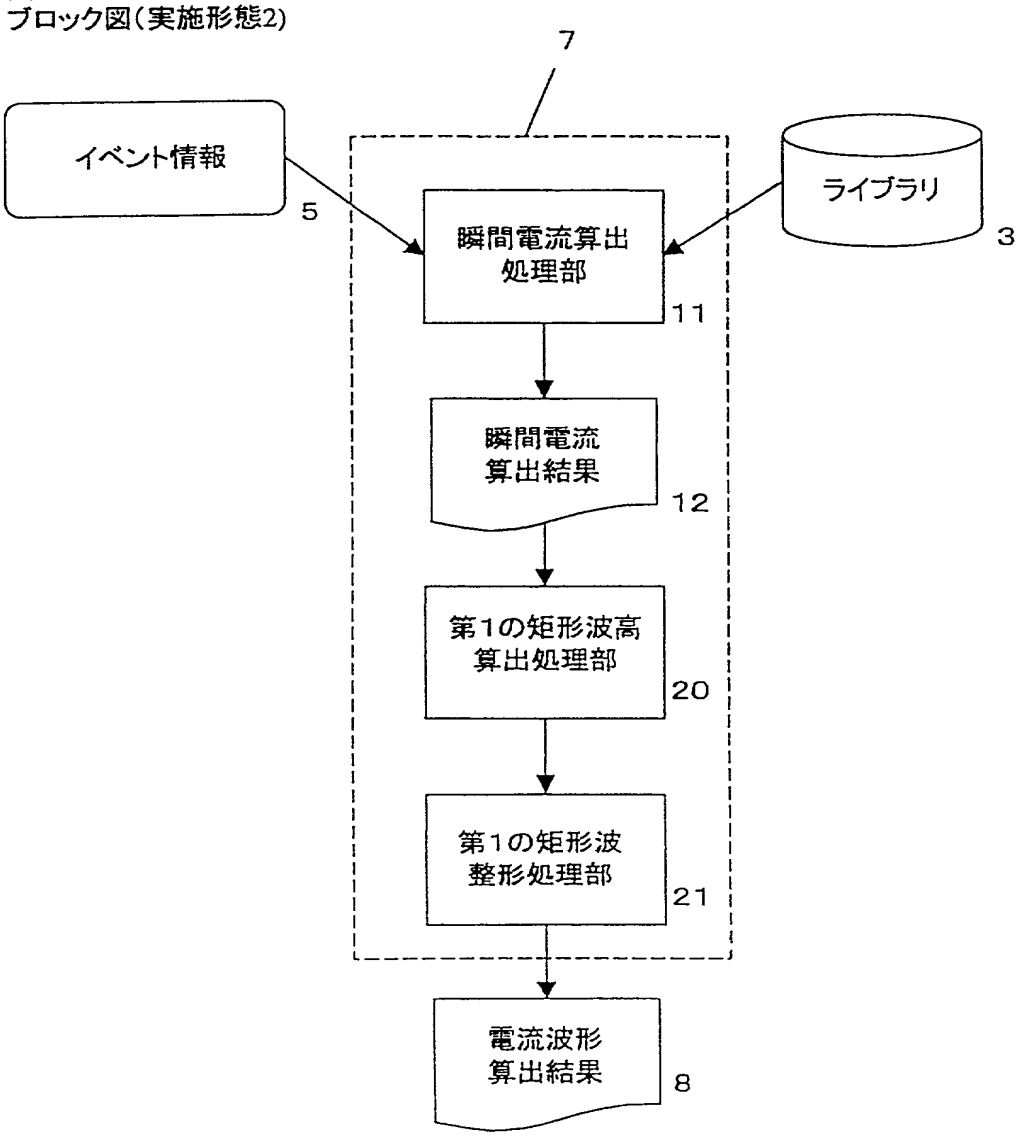


Fig. 8

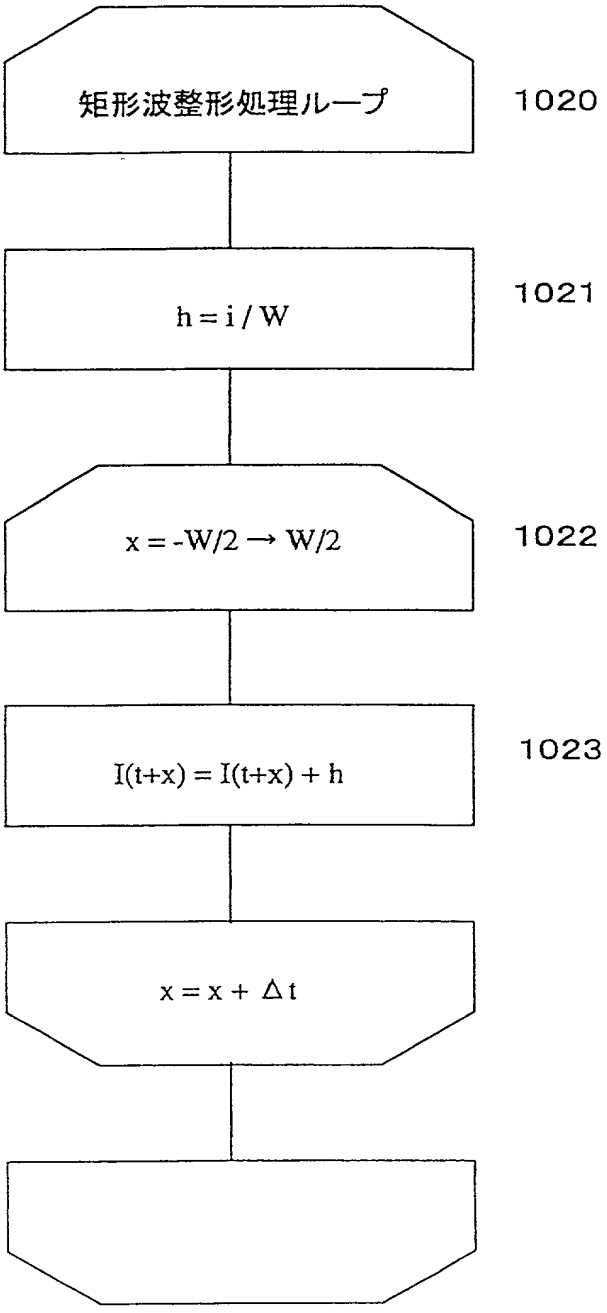
図8電流波形算出処理
ブロック図(実施形態2)



0504503-030400

Fig. 9

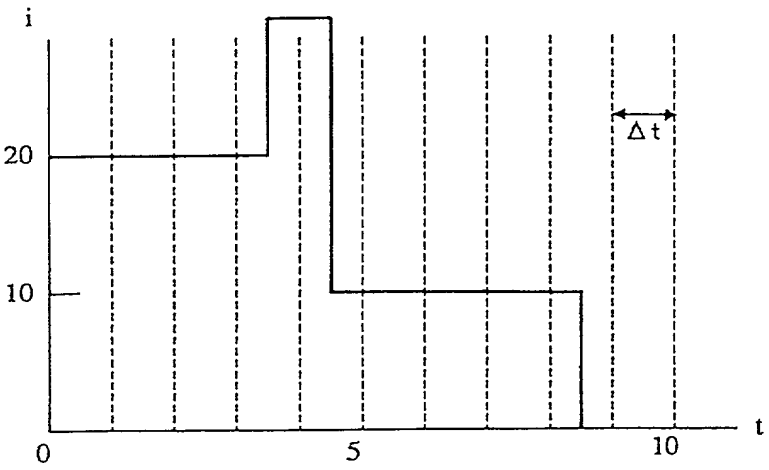
図9 第1の矩形波整形処理フロー図



09E2000-0700200

Fig. 10

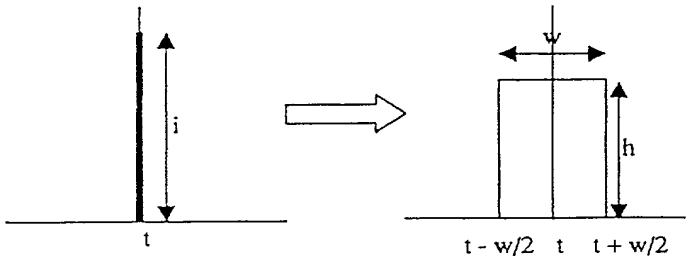
図10 電流波形算出結果(実施形態2)



W＝5 の時

Fig. 11

図11 矩形波モデル(実施形態3)



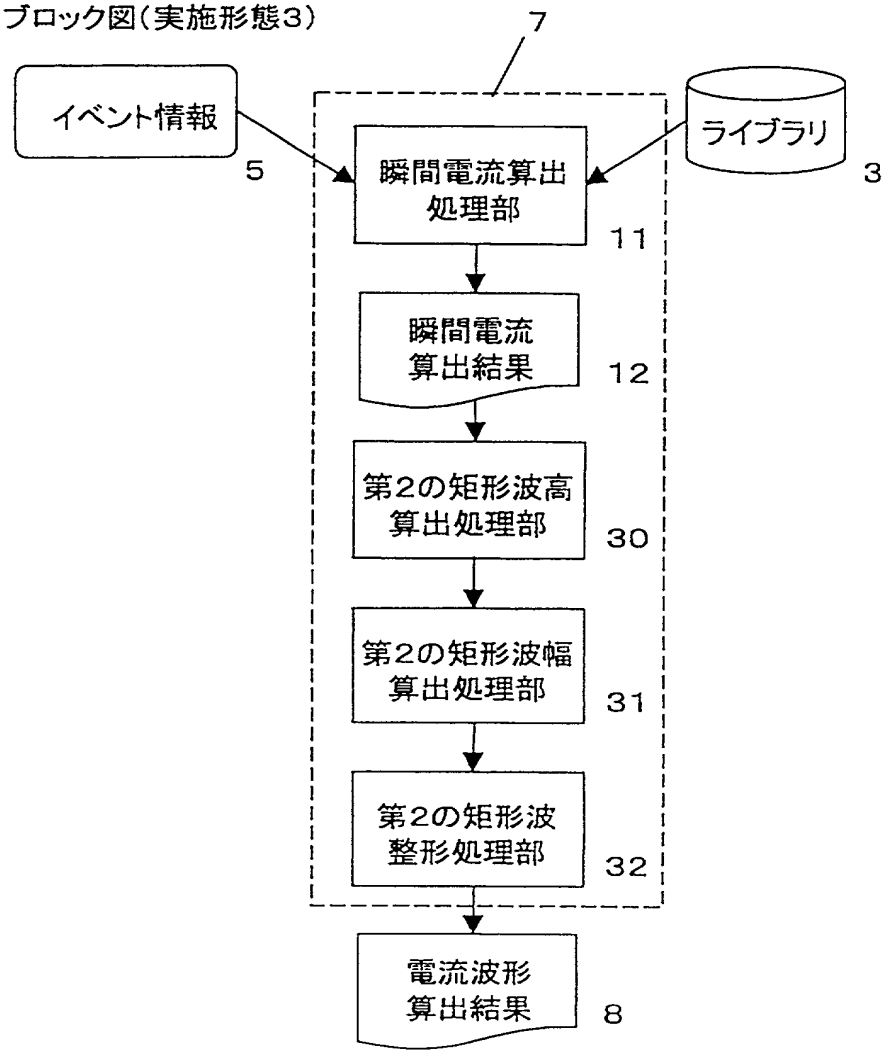
$i = W \times h = \frac{h^2}{K}$

$h = \sqrt{(i \times K)}$

h/w＝K＝一定

Fig. 12

図12 電流波形算出処理
ブロック図(実施形態3)



JP05-503610-033700

Fig. 13

図13 第2の矩形波整形処理フロー図

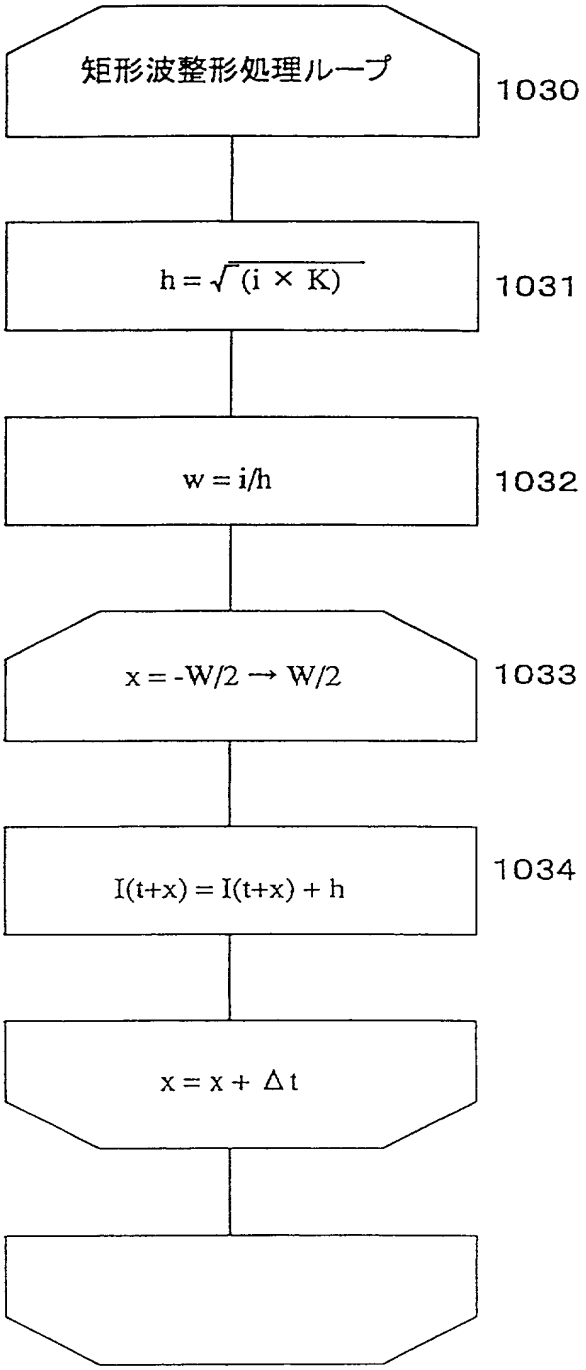
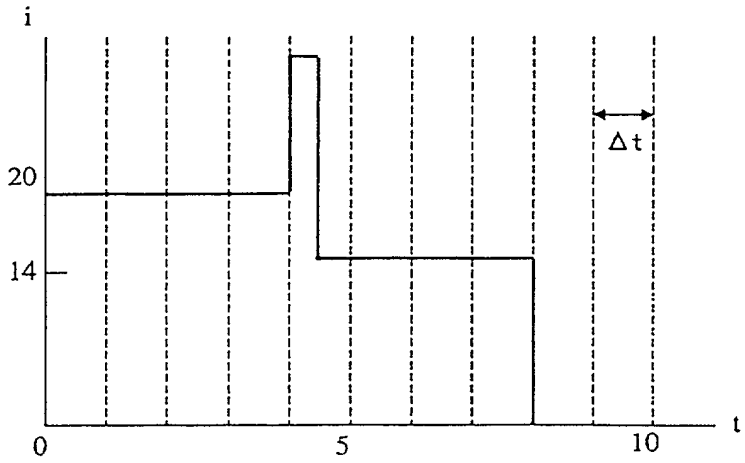


Fig. 14

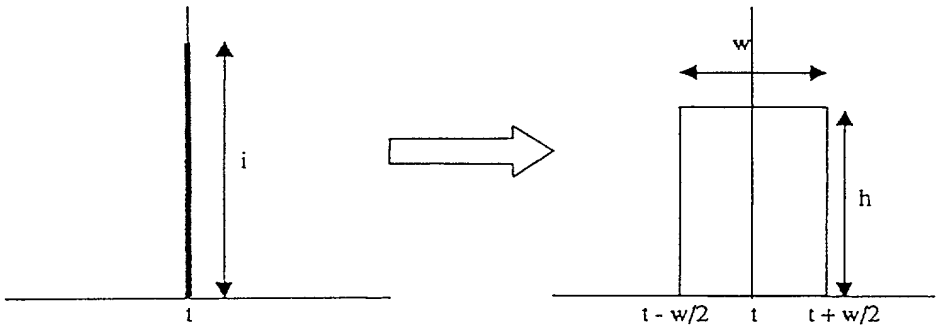
図14 電流波形算出結果(実施形態3)



K＝4の時

Fig. 15

図15 矩形波モデル(実施形態4,5,6)

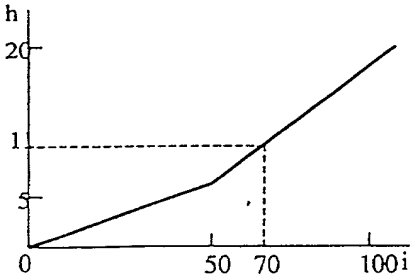


0950582-020200

Fig. 16

図16 i-hテーブル

i	h
0	0
50	5
100	20



i = 70 の場合
(i1,h1)=(50,5)
(i2,h2)=(100,20)

$$h(i)=\frac{h2-h1}{i2-i1}(i-i1)+h1$$

h(70)=11

0376100330

Fig. 17

図17 電流波形算出処理
ブロック図(実施形態4)

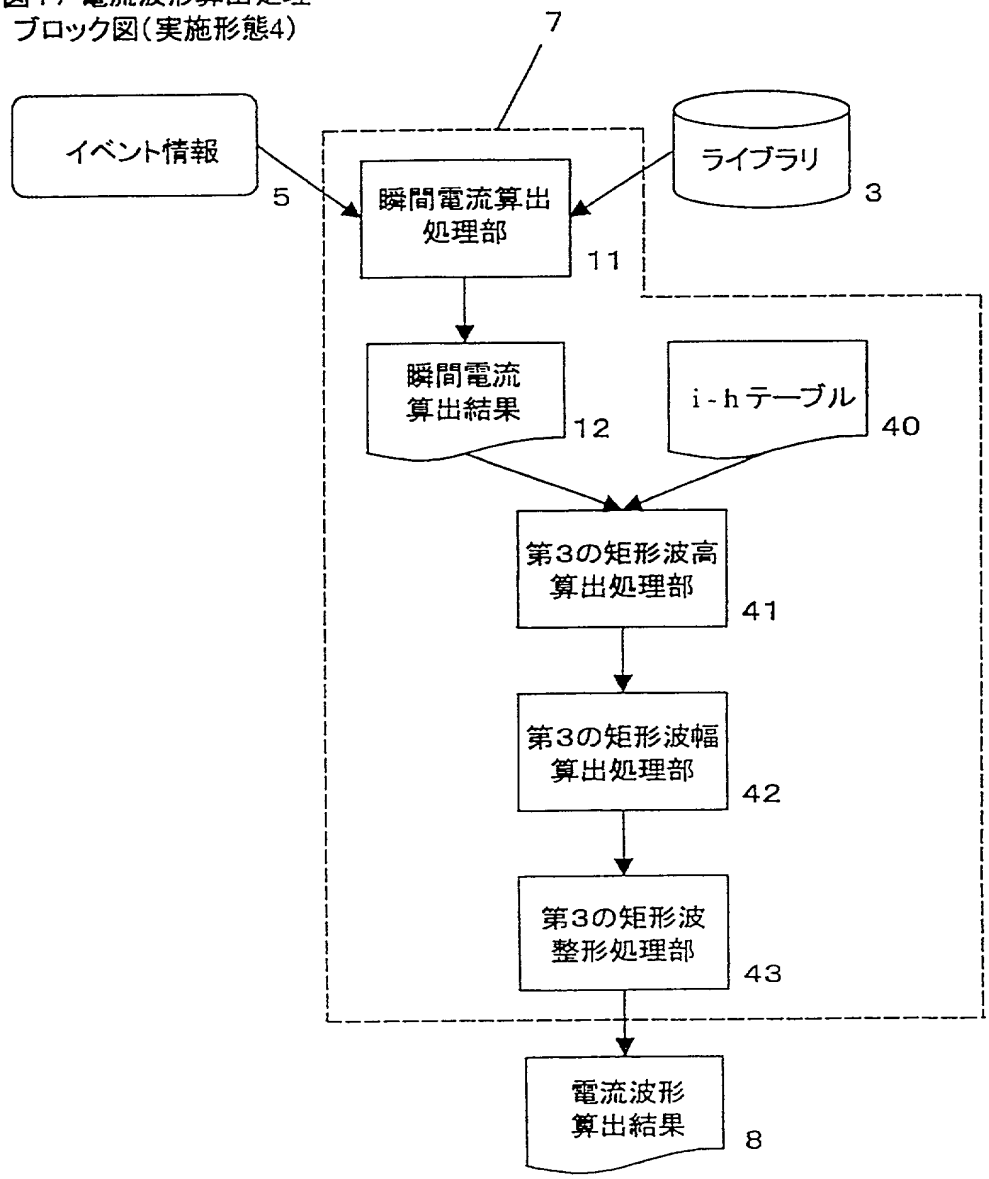
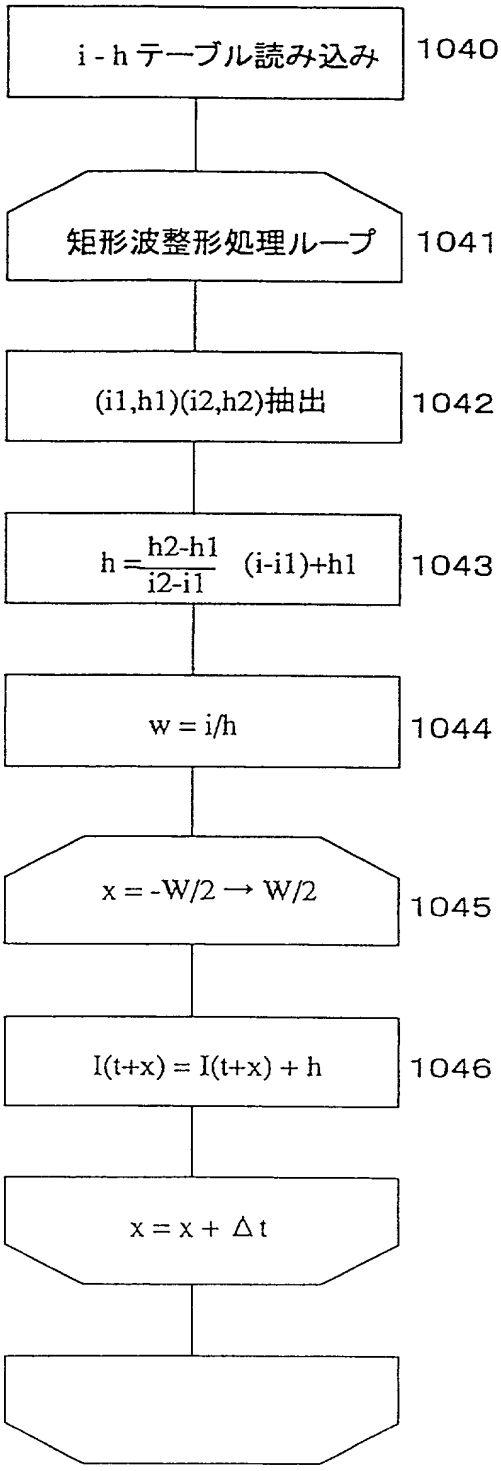


Fig. 18

図18 第3の矩形波整形処理フロー図



09651598-970703

Fig. 19

図19 電流波形算出結果(実施形態4)

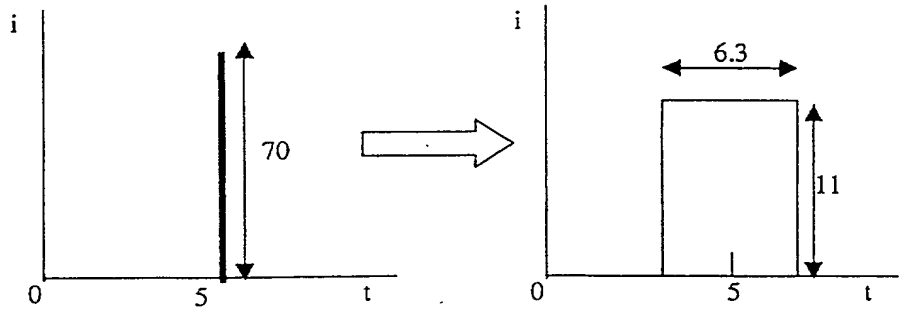
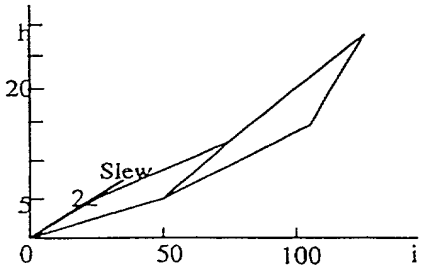


Fig. 20

図 20 i-s-h テーブル

s \ i	0	50	100
0	0	5	14
2	0	6	20



i＝70,s＝1　の場合

s1＝0,s2＝2,i1＝50,i2＝100
h(s1,i1)＝5,h(s1,i2)＝14
h(s2,i1)＝6,h(s2,i2)＝20

$$h(s,i)=\left(\frac{h(s1,i1)(s2-s)}{(s2-s1)}+\frac{h(s2,i1)(s-s1)}{(s2-s1)}\right)\left(\frac{i2-i}{i2-i1}\right)+\left(\frac{h(s1,i2)(s2-s)}{(s2-s1)}+\frac{h(s2,i2)(s-s1)}{(s2-s1)}\right)\left(\frac{i-i1}{i2-i1}\right)$$

h(1,70)＝10.1

0037610033

Fig. 21

図21 電流波形算出処理
ブロック図(実施形態5)

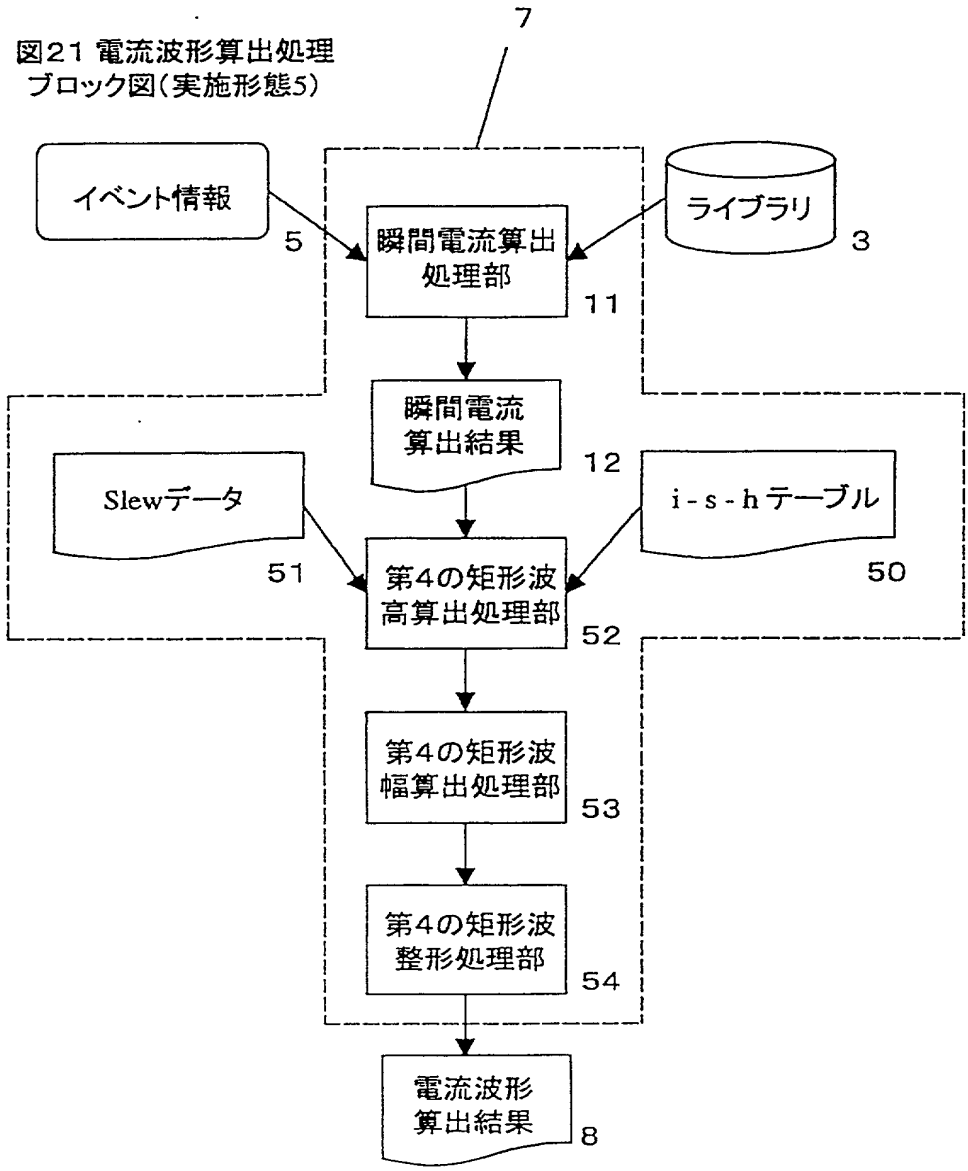


Fig. 22

図22 第4の矩形波整形処理フロー図

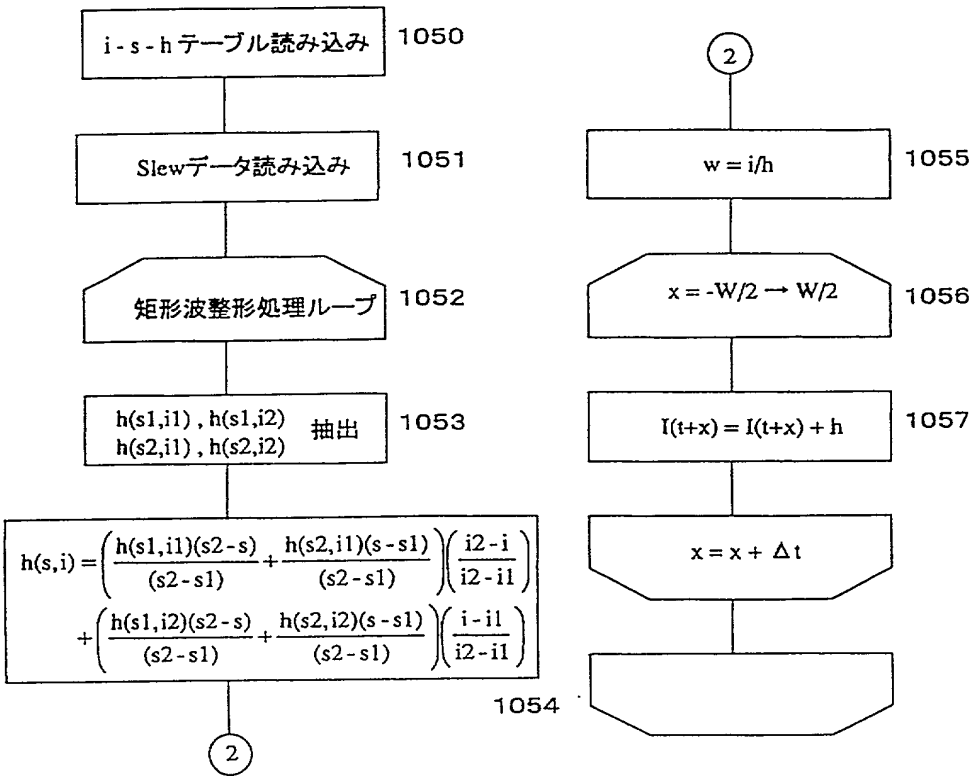


Fig. 23

図23 電流波形算出結果(実施形態5)

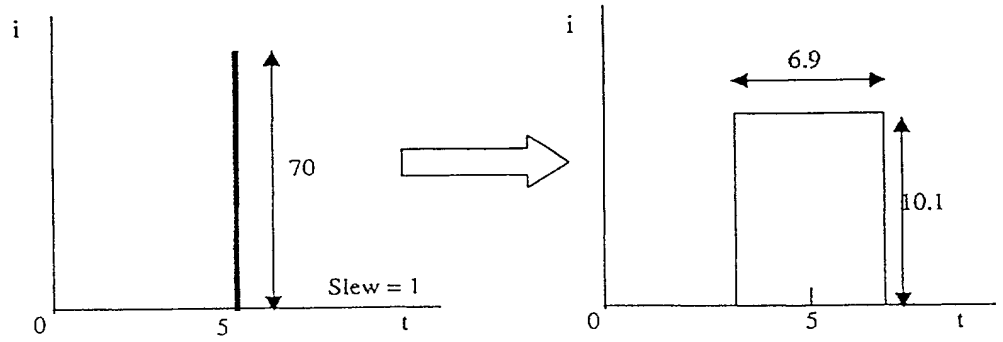
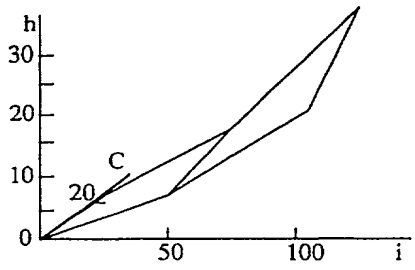


Fig. 24

図24 i - c - h テーブル

C \ i	0	50	100
0	0	5	20
20	0	8	25



i＝70, c＝10の場合

c1＝0, c2＝20, i1＝50, i2＝100

h(c1, i1)＝5, h(c1, i2)＝20

h(c2, i1)＝8, h(c2, i2)＝25

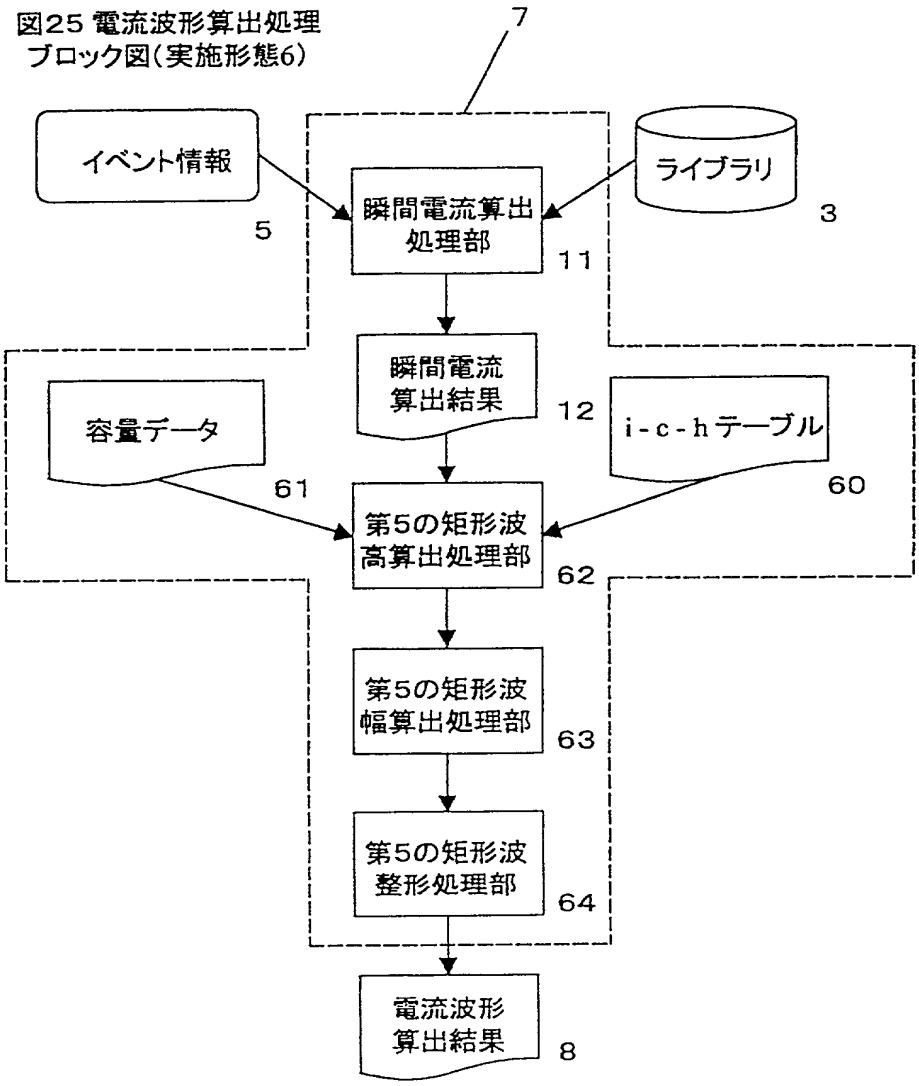
$$h(s,i)=\left(\frac{h(c1,i1)(c2-c)}{(c2-c1)}+\frac{h(c2,i1)(c-c1)}{(c2-c1)}\right)\left(\frac{i2-i}{i2-i1}\right)+\left(\frac{h(c1,i2)(c2-c)}{(c2-c1)}+\frac{h(c2,i2)(c-c1)}{(c2-c1)}\right)\left(\frac{i-i1}{i2-i1}\right)$$

h(10,70)＝12.9

JP2000-020055

Fig. 25

図25 電流波形算出処理
ブロック図(実施形態6)



0056252-030700

Fig. 26

図26 第5の矩形波整形処理フロー図

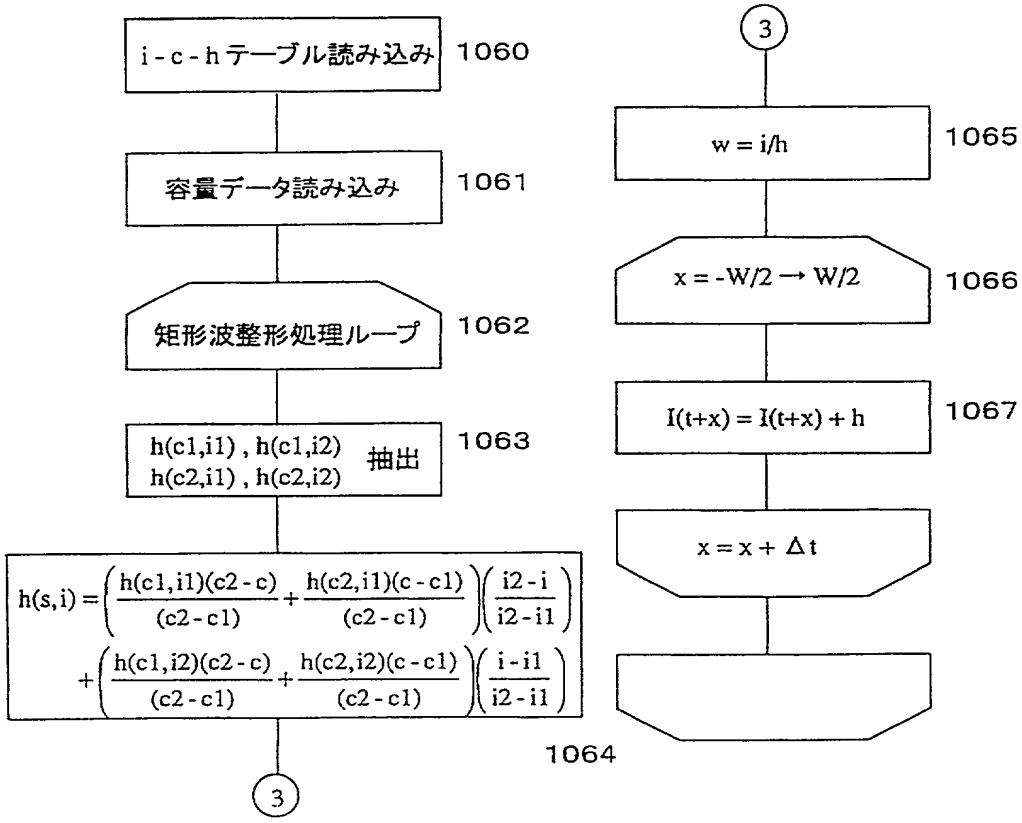


Fig. 27

図27 電流波形算出結果(実施形態6)

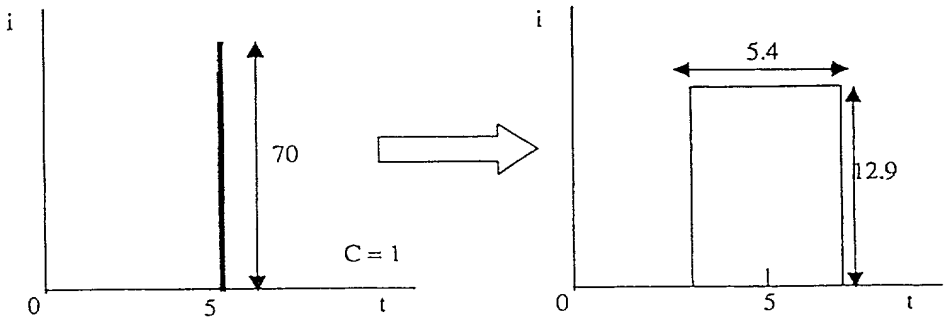


Fig. 28

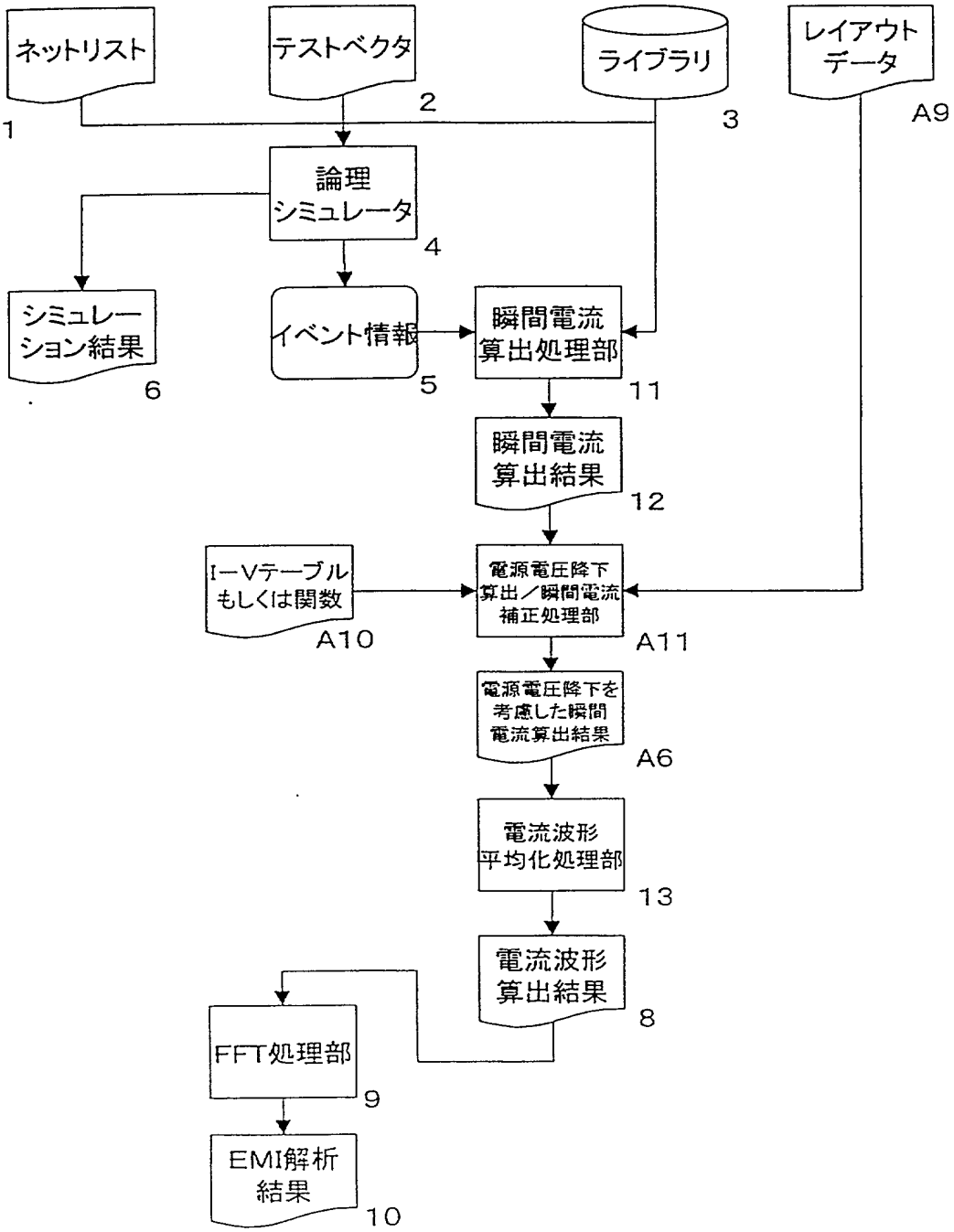

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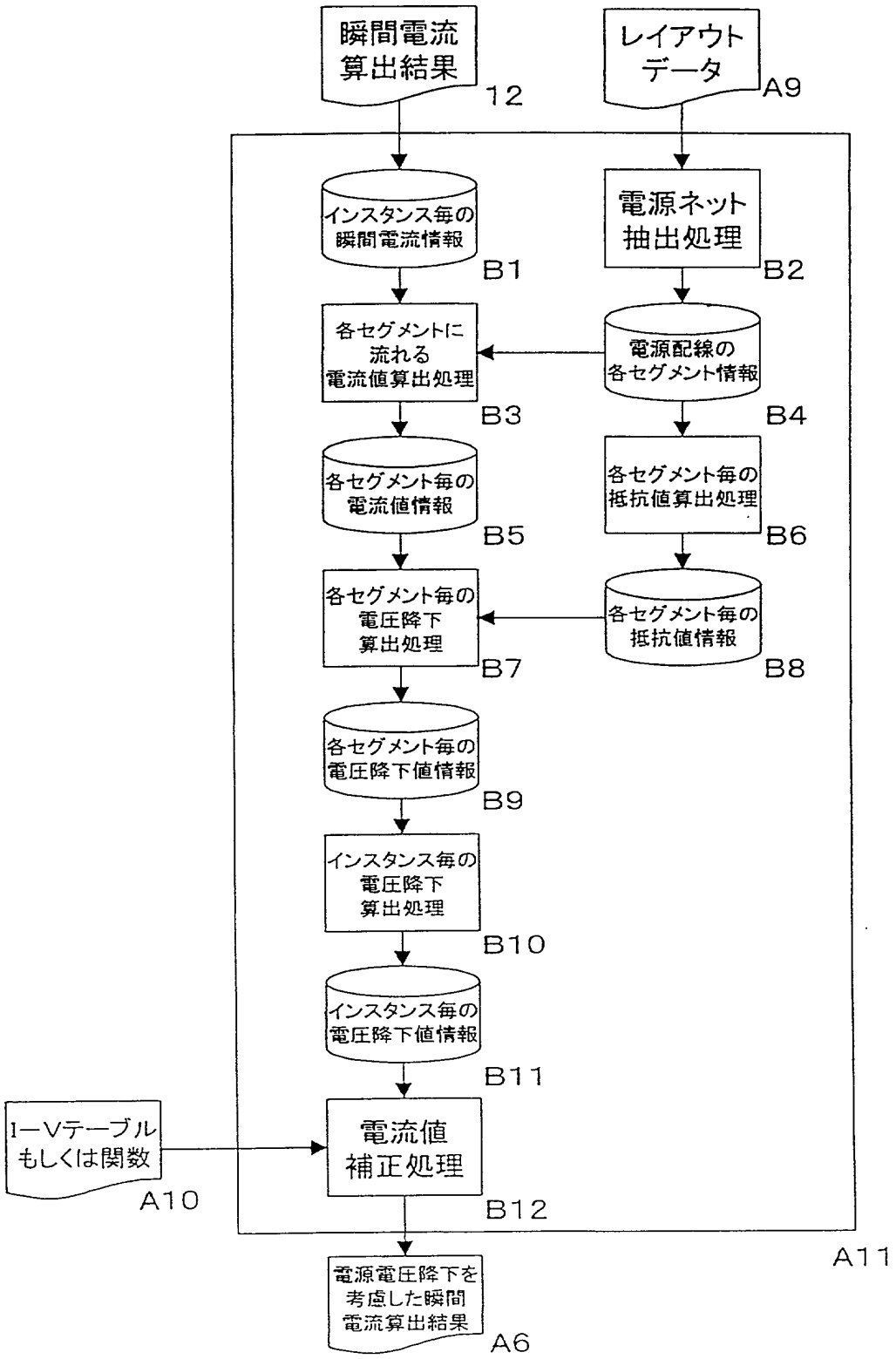

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Fig. 30

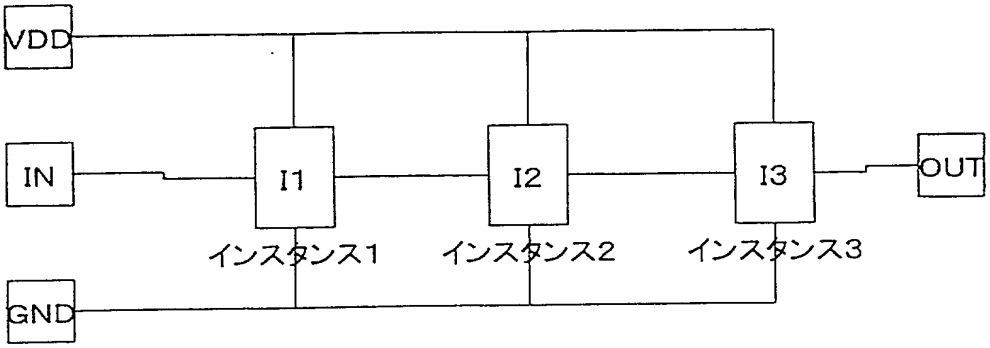


Fig. 31

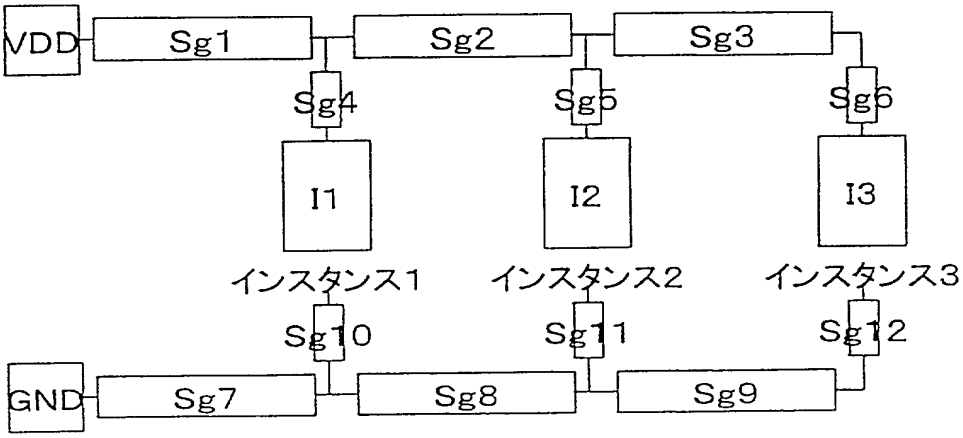


Fig. 32

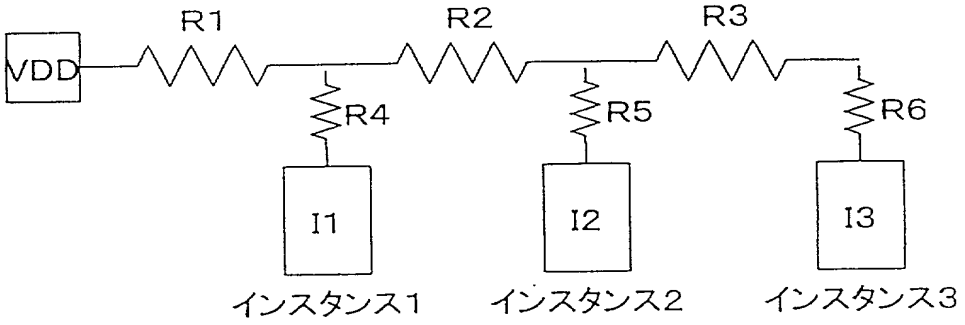
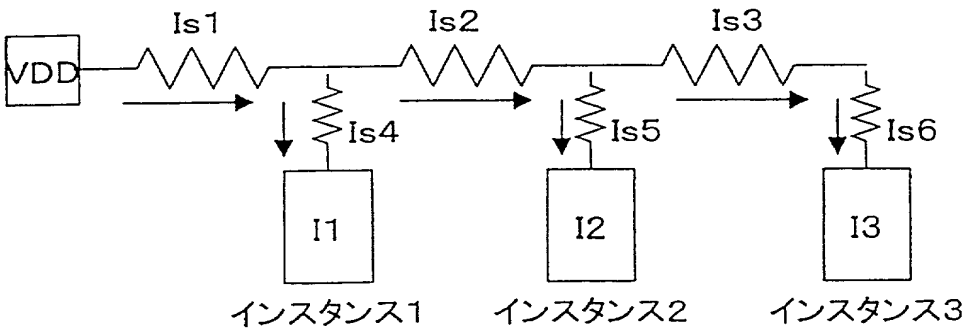
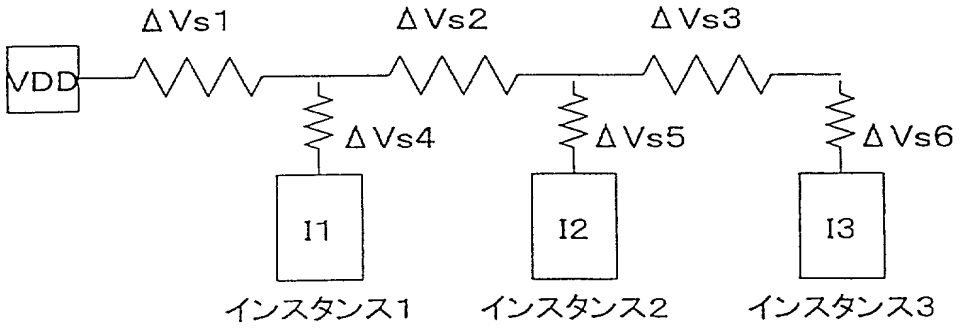


Fig. 33



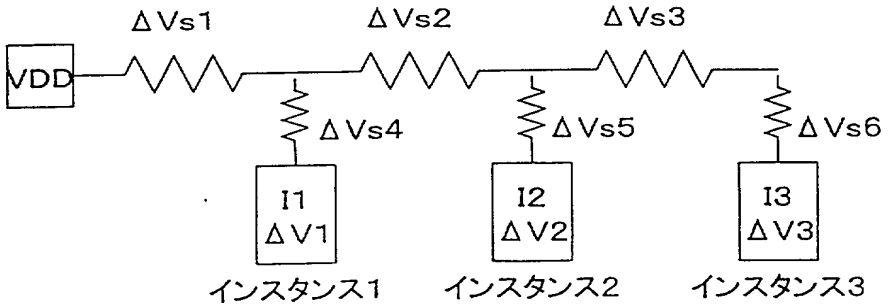
Is1＝I1＋I2＋I3
Is2＝I2＋I3
Is3＝I3
Is4＝I1
Is5＝I2
Is6＝I3

Fig. 34



ΔVs1＝R1＊Is1
ΔVs2＝R2＊Is2
ΔVs3＝R3＊Is3
ΔVs4＝R4＊Is4
ΔVs5＝R5＊Is5
ΔVs6＝R6＊Is6

Fig. 35



インスタンス1の電圧降下：ΔV1＝ΔVs1＋ΔVs4
インスタンス2の電圧降下：ΔV2＝ΔVs1＋ΔVs2＋ΔVs5
インスタンス3の電圧降下：ΔV3＝ΔVs1＋ΔVs2＋ΔVs3＋ΔVs6

0 5 2 5 8 2 - 0 3 0 6 0 5

Fig. 36

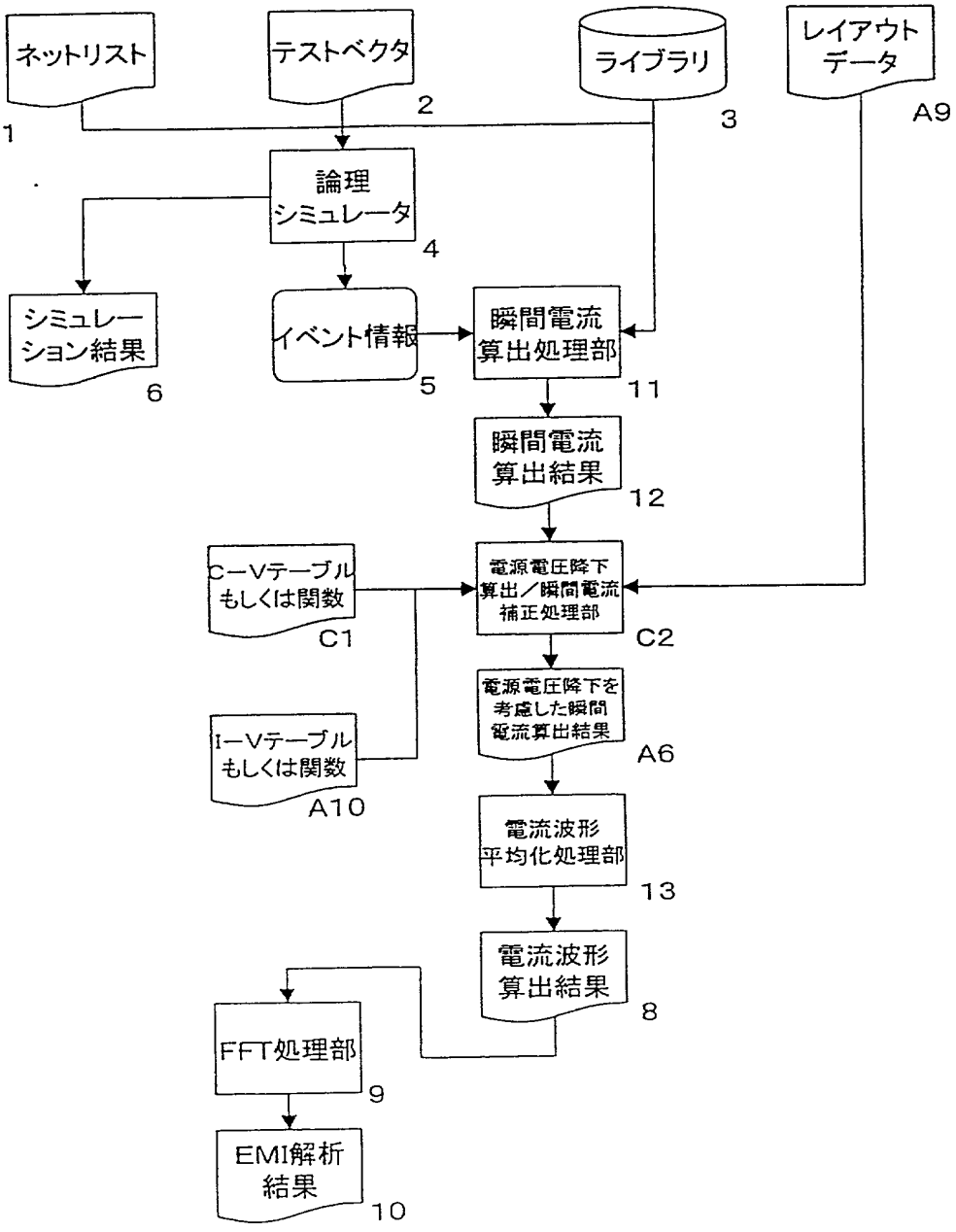

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Fig. 37

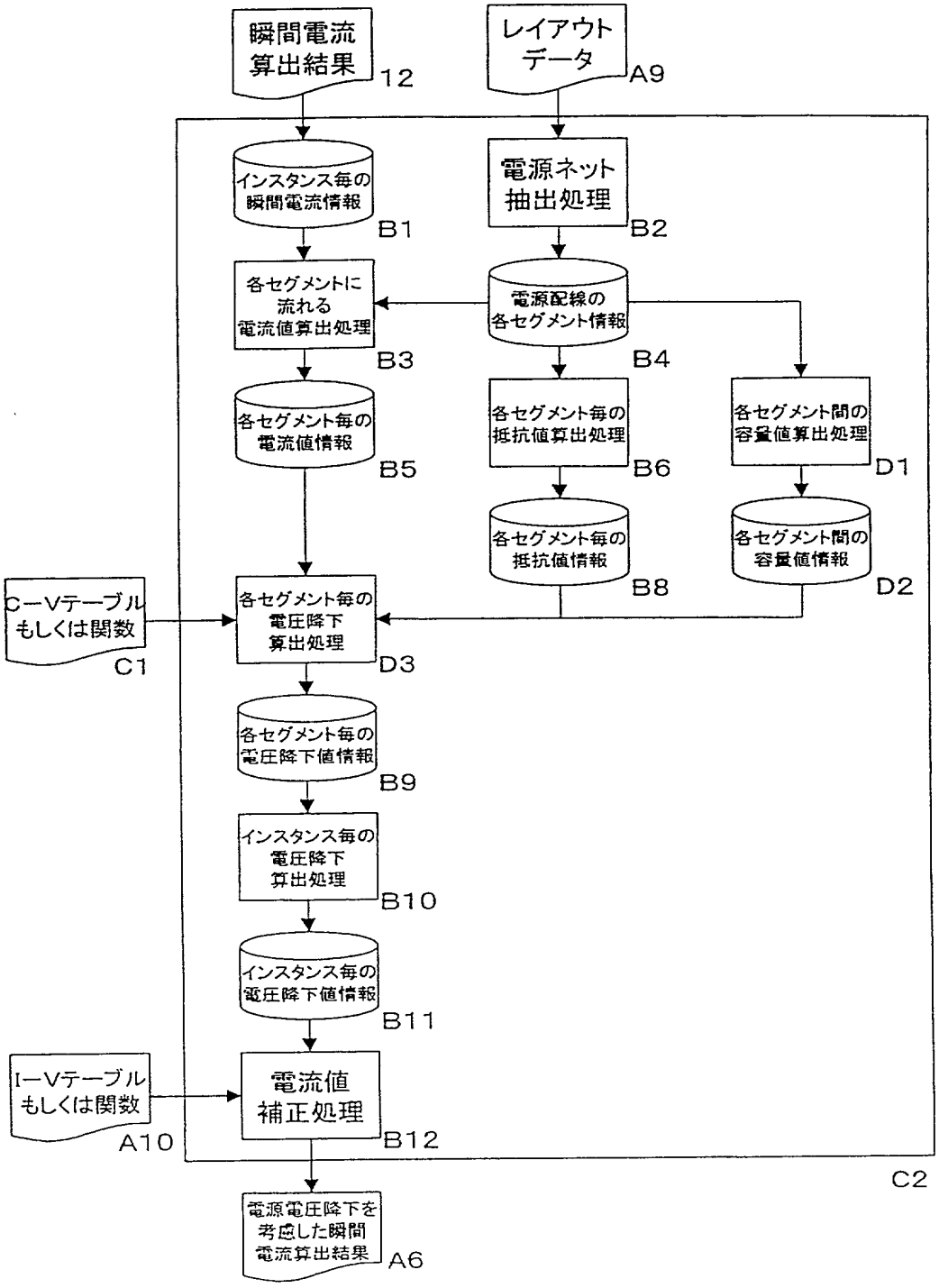

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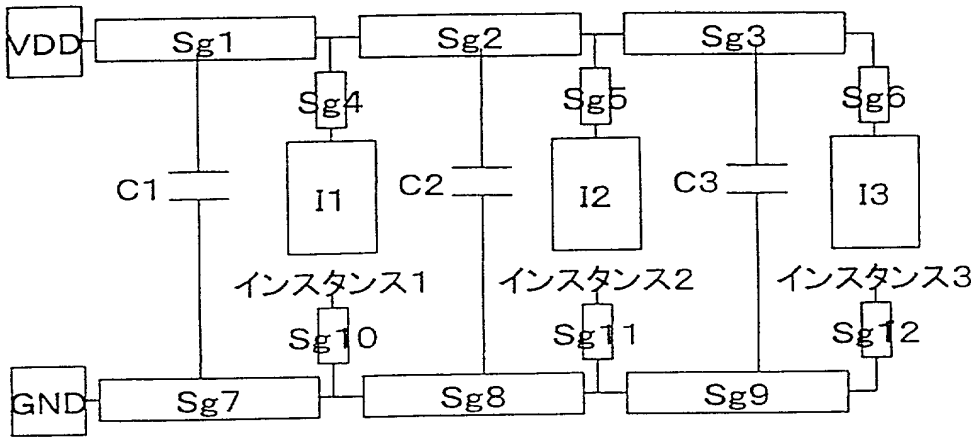
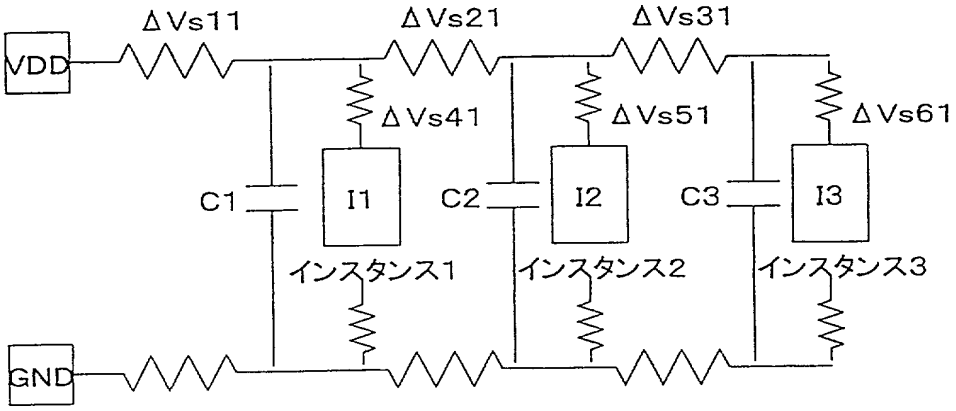


Fig. 39



ΔVs11＝f(C1、ΔVs1)
ΔVs21＝f(C2、ΔVs2)
ΔVs31＝f(C3、ΔVs3)
ΔVs41＝ΔVs4
ΔVs51＝ΔVs5
ΔVs61＝ΔVs6

インスタンス1の電圧降下：ΔV1＝ΔVs11＋ΔVs41
インスタンス2の電圧降下：ΔV2＝ΔVs11＋ΔVs21＋ΔVs51
インスタンス3の電圧降下：ΔV3＝ΔVs11＋ΔVs21＋ΔVs31＋ΔVs61

Fig. 40

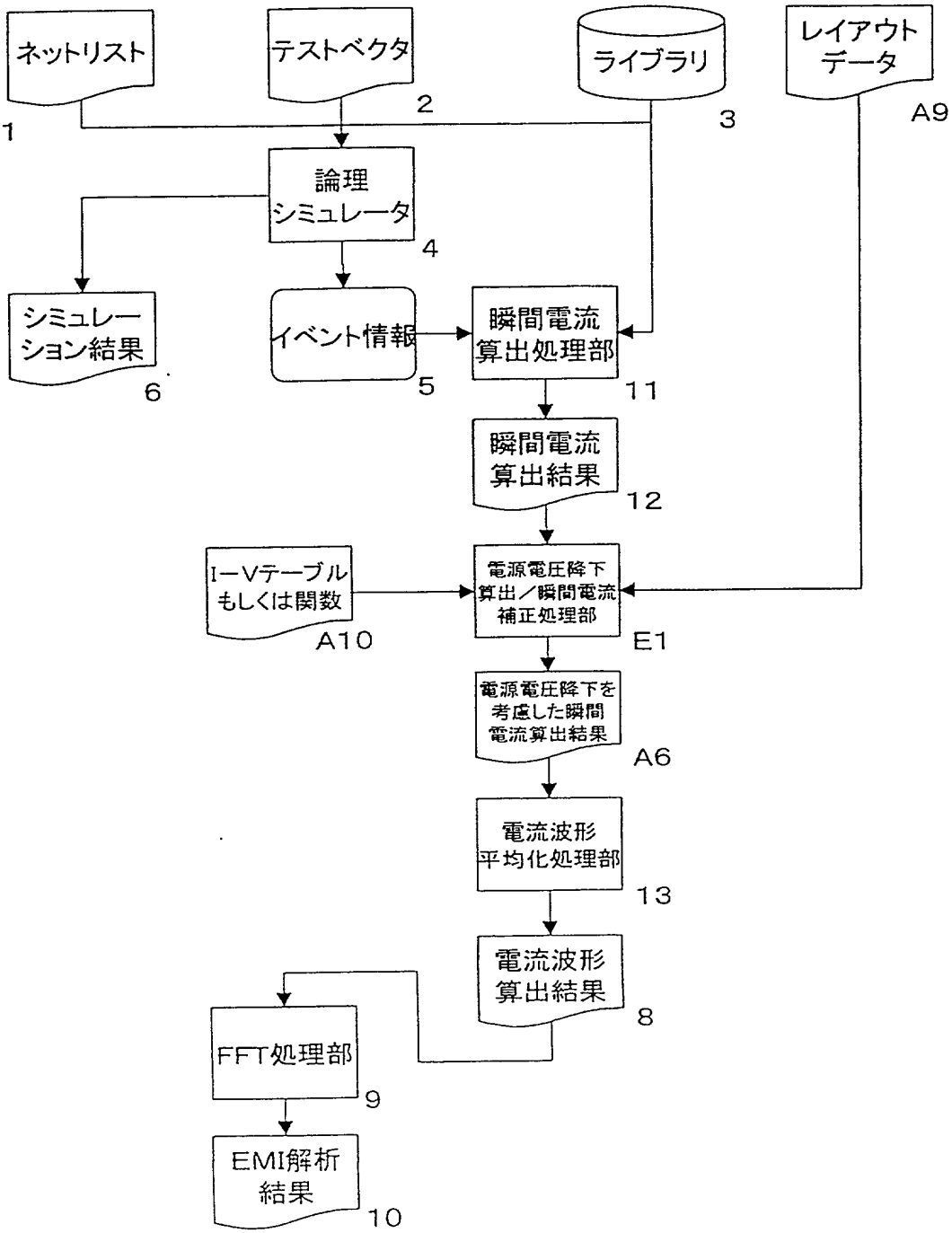

ネットリスト
1
テストベクタ
2
ライブラリ
3
レイアウトデータ
A9
論理シミュレータ
4
シミュレーション結果
6
イベント情報
5
瞬間電流算出処理部
11
瞬間電流算出結果
12
I−Vテーブルもしくは関数
A10
電源電圧降下算出／瞬間電流補正処理部
E1
電源電圧降下を考慮した瞬間電流算出結果
A6
電流波形平均化処理部
13
電流波形算出結果
8
FFT処理部
9
EMI解析結果
10

Fig. 41

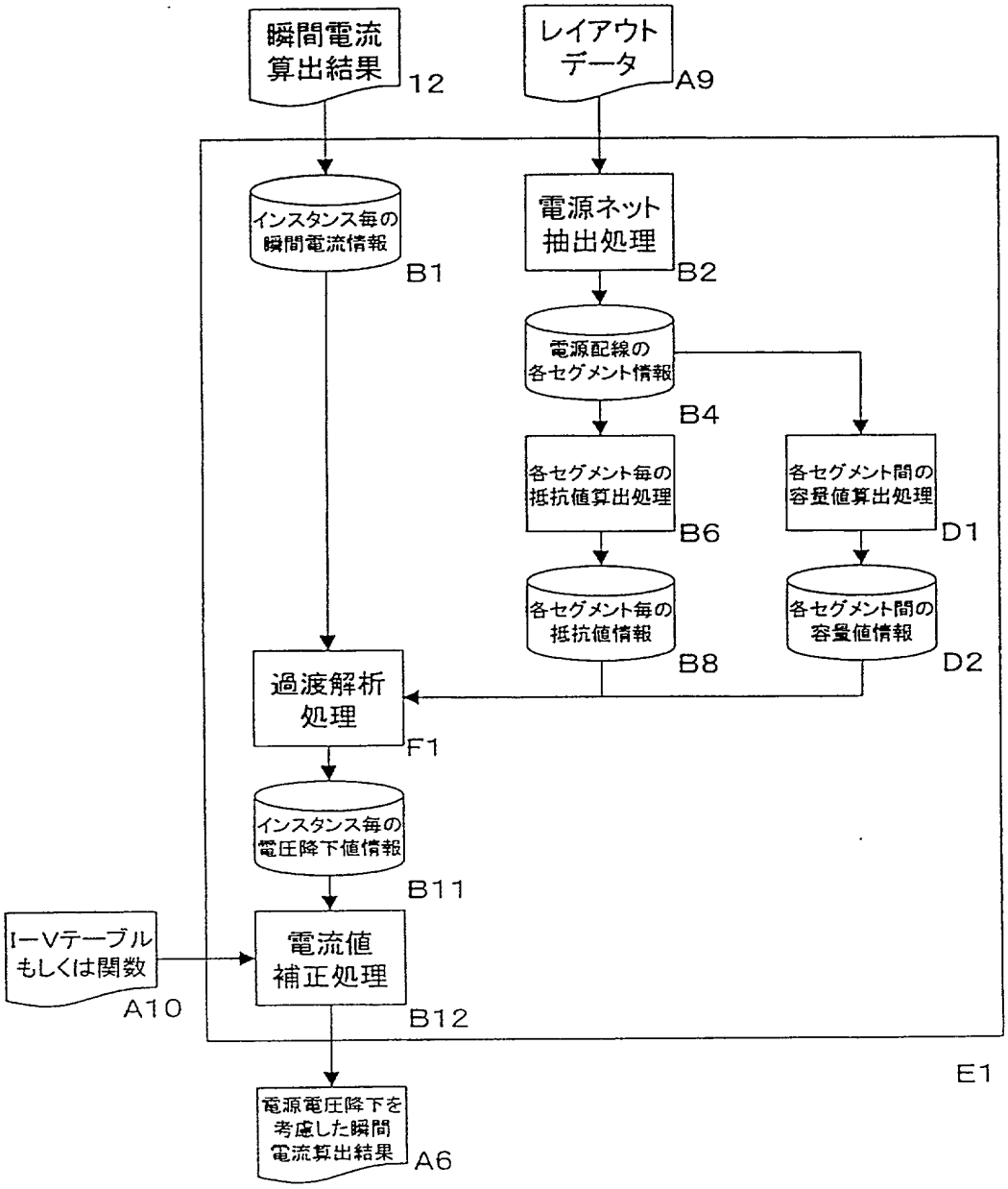
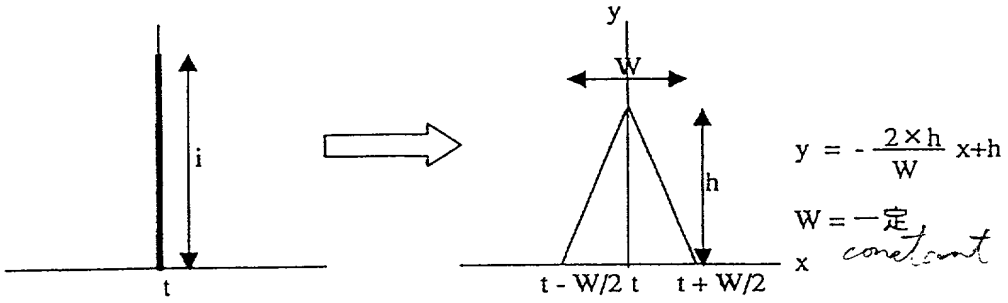

瞬間電流
算出結果
12
レイアウト
データ
A9
インスタンス毎の
瞬間電流情報
B1
電源ネット
抽出処理
B2
電源配線の
各セグメント情報
B4
各セグメント毎の
抵抗値算出処理
B6
各セグメント間の
容量値算出処理
D1
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抵抗値情報
B8
各セグメント間の
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D2
過渡解析
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B11
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A10
電流値
補正処理
B12
E1
電源電圧降下を
考慮した瞬間
電流算出結果
A6

Fig. 42

図42 三角波モデル(実施形態10)



0950-0702-0000

Fig. 43

図43 電流波形算出処理
ブロック図(実施形態10)

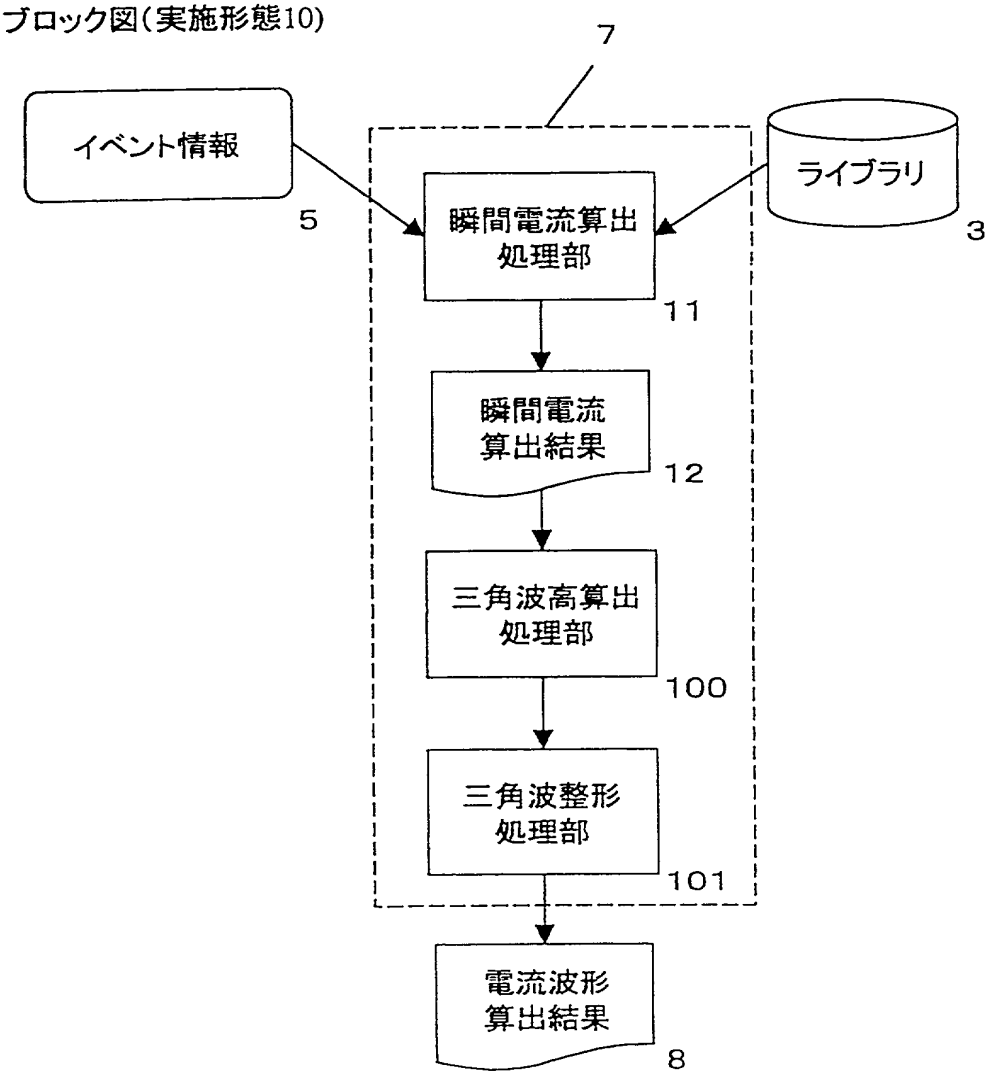


Fig. 44

図44 三角波整形処理フロー図

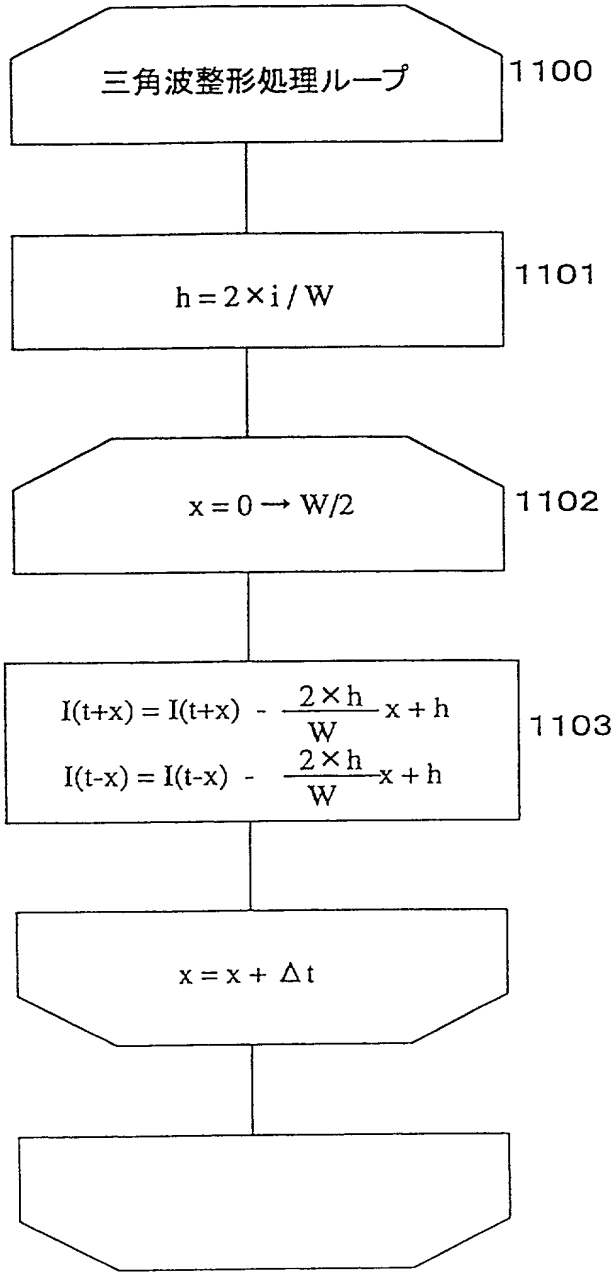
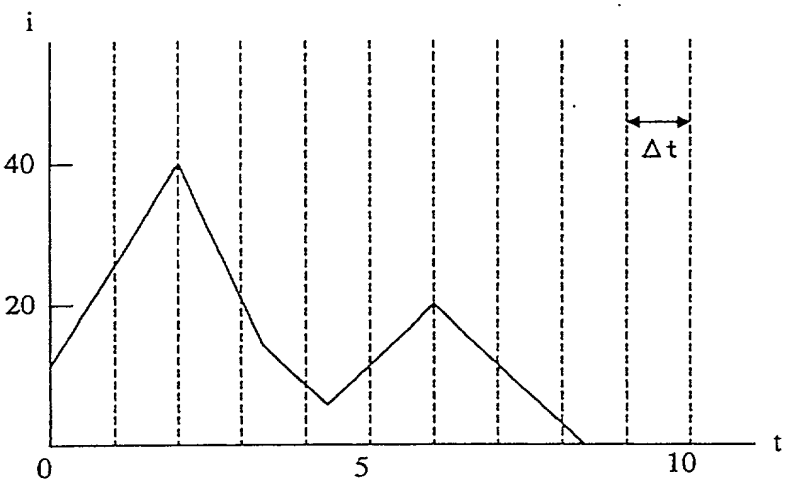


Fig. 45

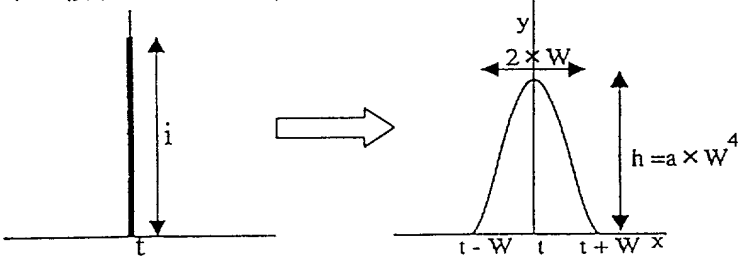
図45 電流波形算出結果(実施形態10)



W＝5 の時

Fig. 46

図46 複数次関数モデル(実施形態11)



W＝一定

$y = a(x - W)^2(x + W)^2$

$a = \frac{15}{16 \times W^5} i$

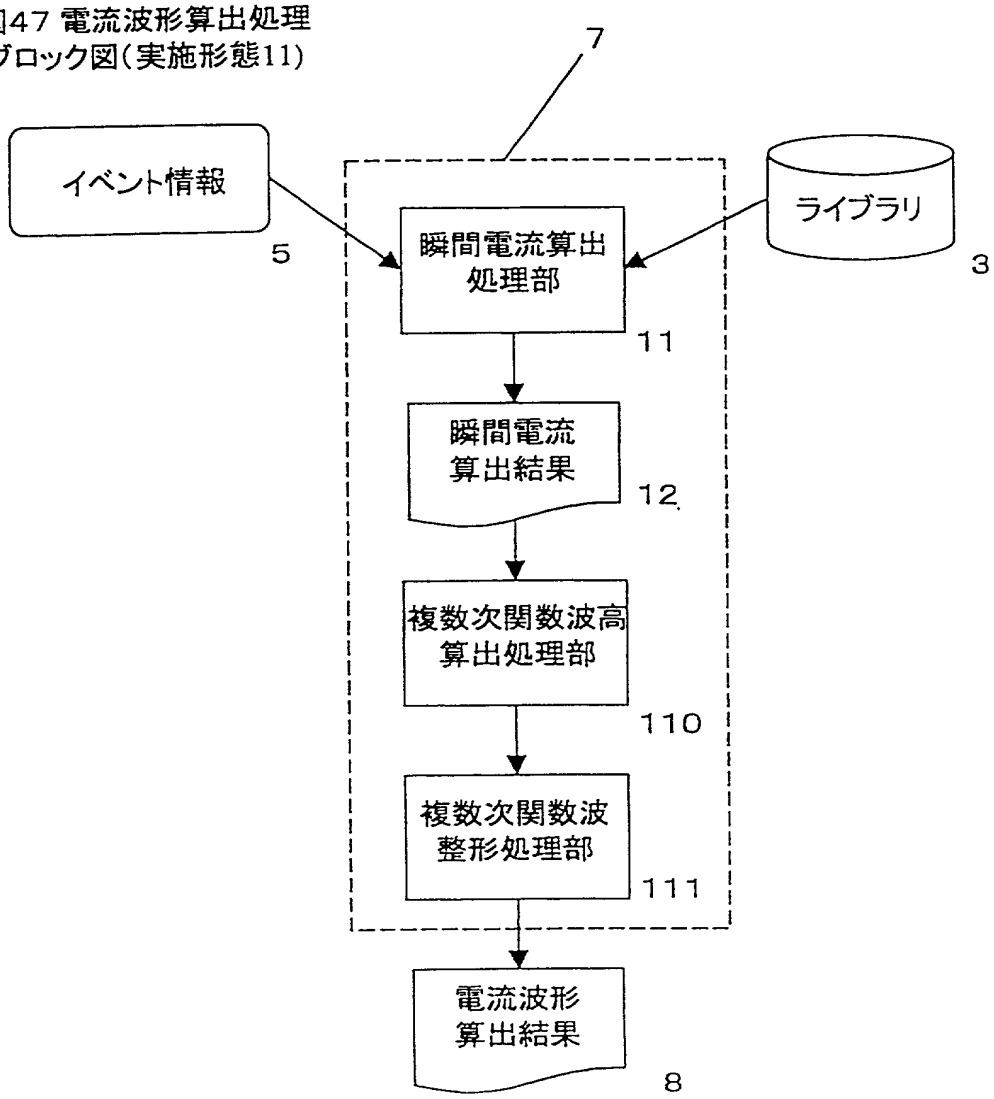
W＝2.5 , i＝100 の時
a＝0.96
h＝37.5

W＝2.5 , i＝50 の時
a＝0.48
h＝18.75

0950258-070700

Fig. 47

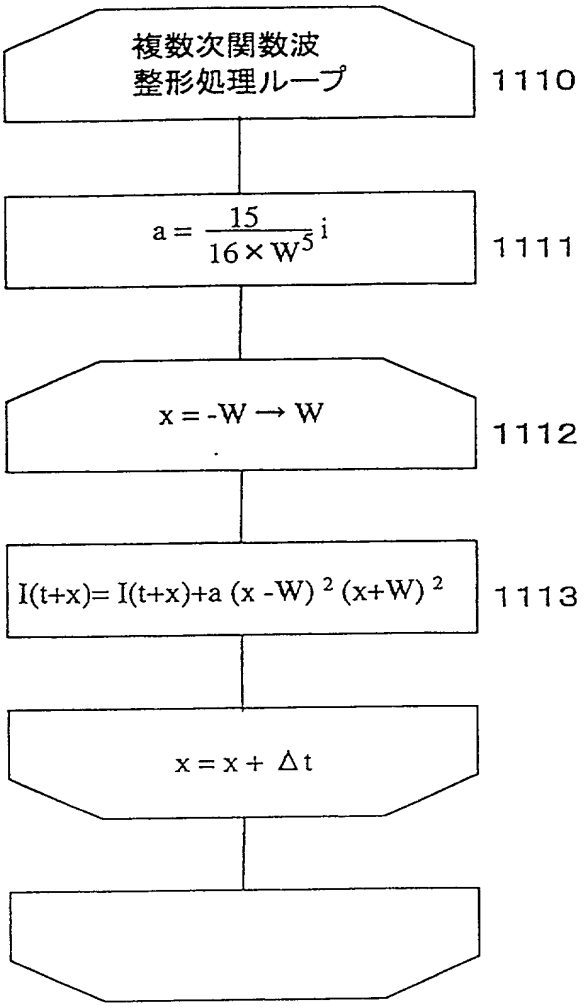
図47 電流波形算出処理
ブロック図(実施形態11)



09.12.08 09:08:08

Fig. 48

図48 複数次関数整形処理フロー図



DOCUMENT-ID: JP 5037610033

Fig. 49

図49 電流波形算出結果(実施形態11)

W＝2.5 の時

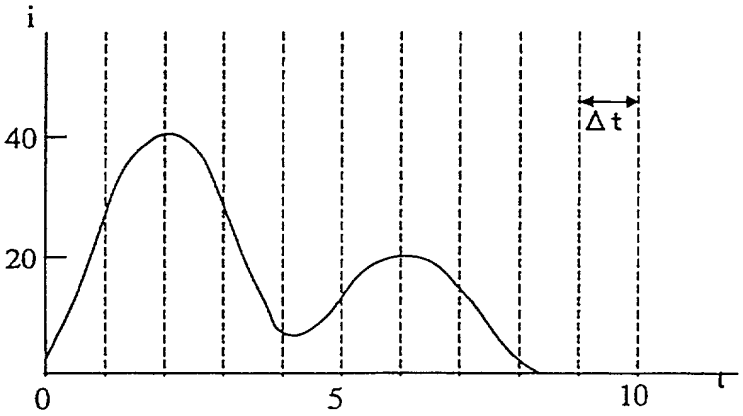
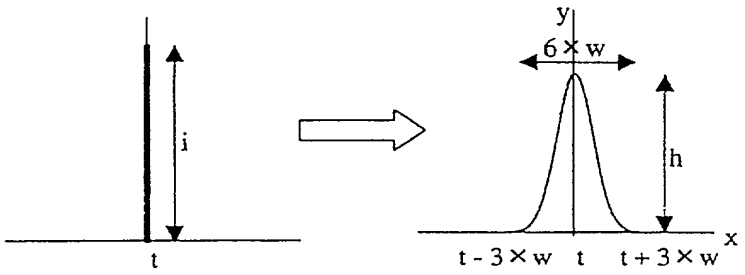


Fig. 50

図50 ガウス関数モデル(実施形態12,25)

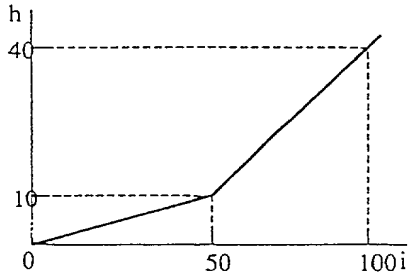


$$y = h \times e^{-\left(\frac{x}{w}\right)^2}$$

Fig. 51

図51 i-hテーブル

i	h
0	0
50	10
100	40



i＝50，100 の場合
(i1,h1)=(50,5)
(i2,h2)=(100,20)

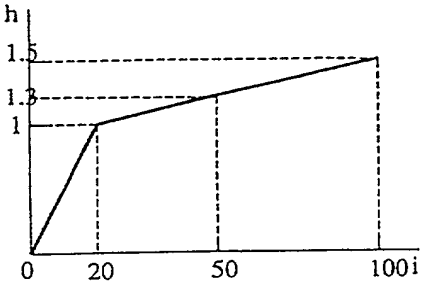
$$h(i) = \frac{h2-h1}{i2-i1}(i-i1)+h1$$

h(50)=10
h(100)=40

Fig. 52

図52 i - w テーブル

i	w
0	0
20	1
100	1.5



i＝50，100 の場合
(i1,w1)=(20,1)
(i2,w2)=(100,1.5)

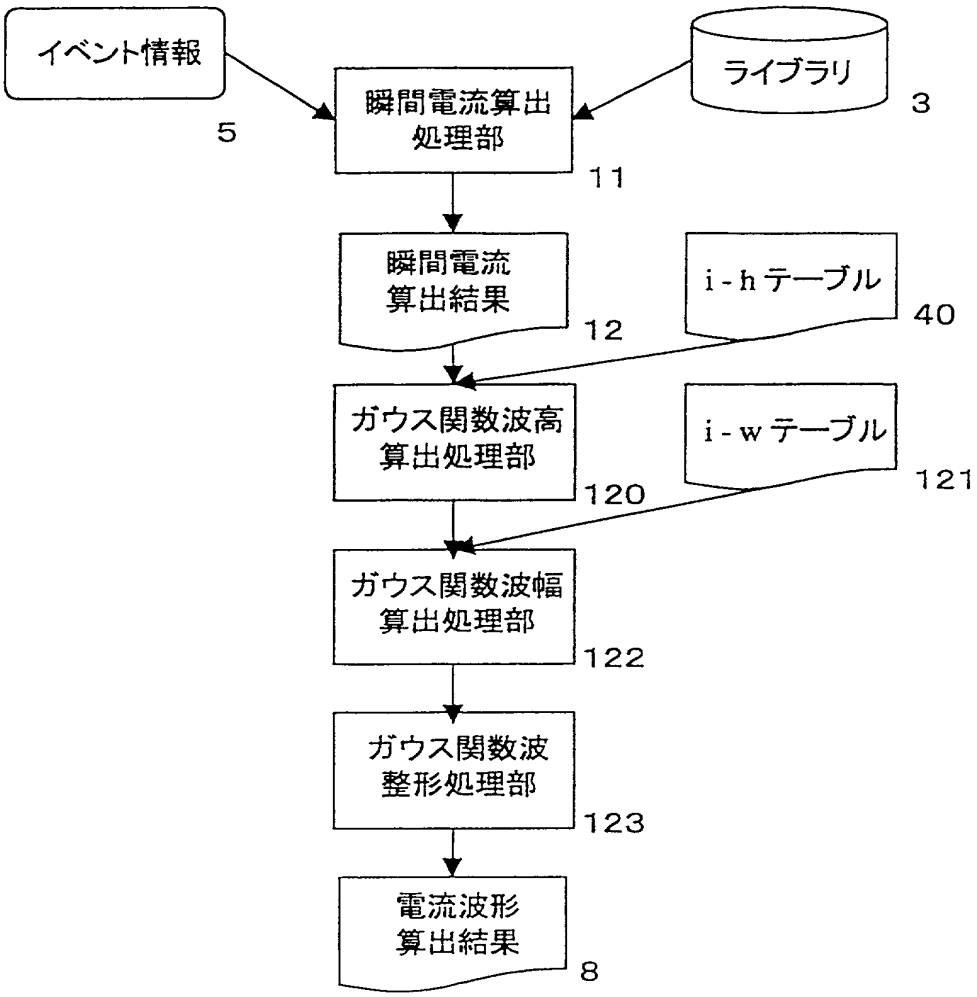
$$w(i)=\frac{w2-w1}{i2-i1}(i-i1)+w1$$

w(50)=1.3
w(100)=1.5

0050750210

Fig. 53

図53 電流波形算出処理
ブロック図(実施形態12)



0358250-070900

Fig. 54

図54 ガウス波整形処理フロー図

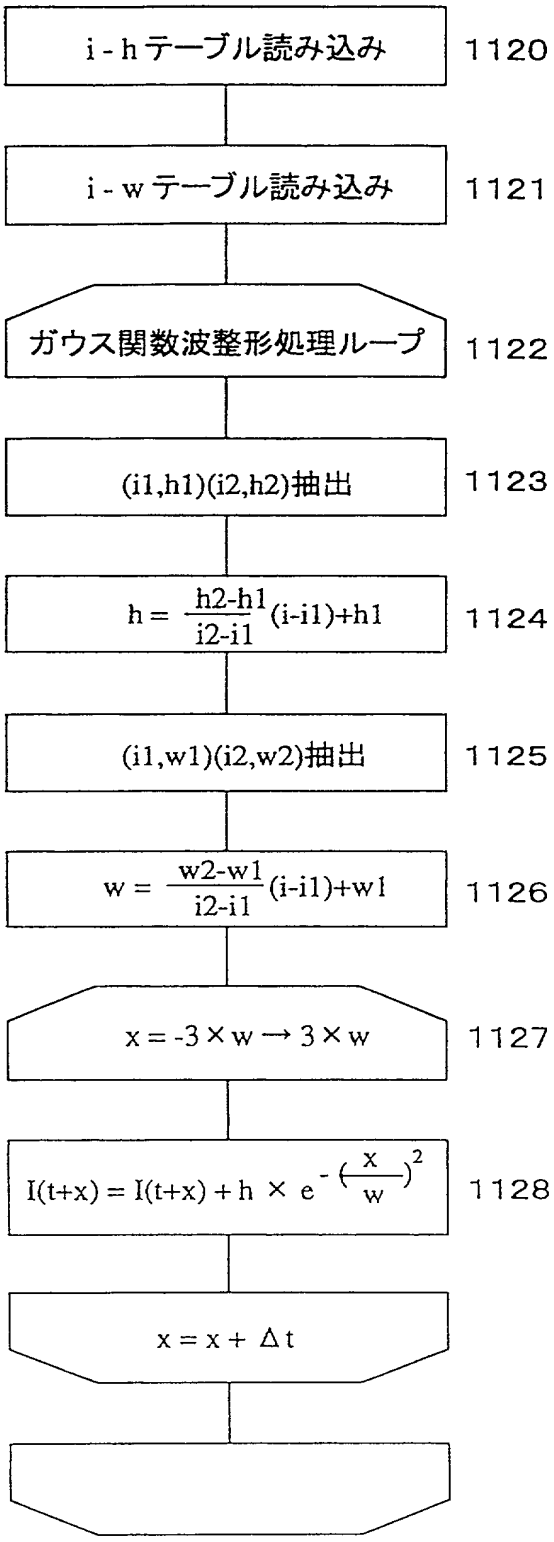
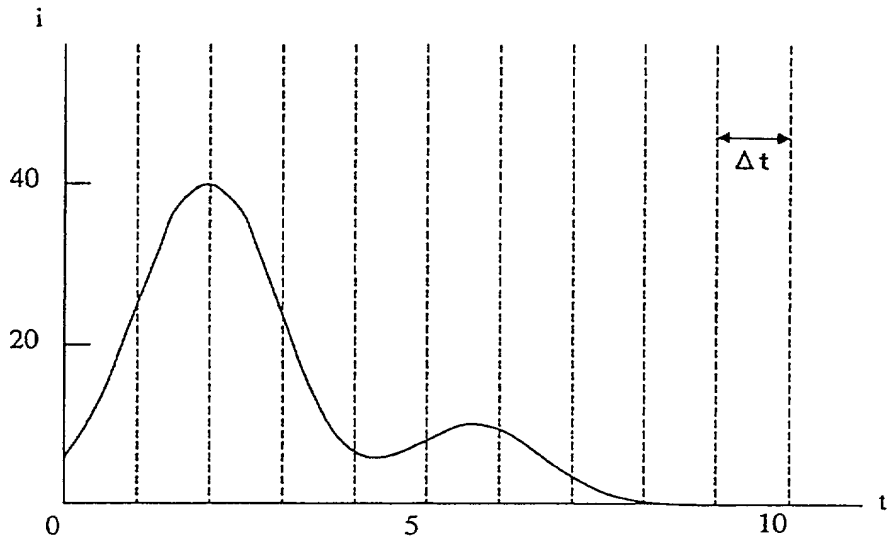


Fig. 55

図55 電流波形算出結果(実施形態12)



0950253-070700

Fig. 56

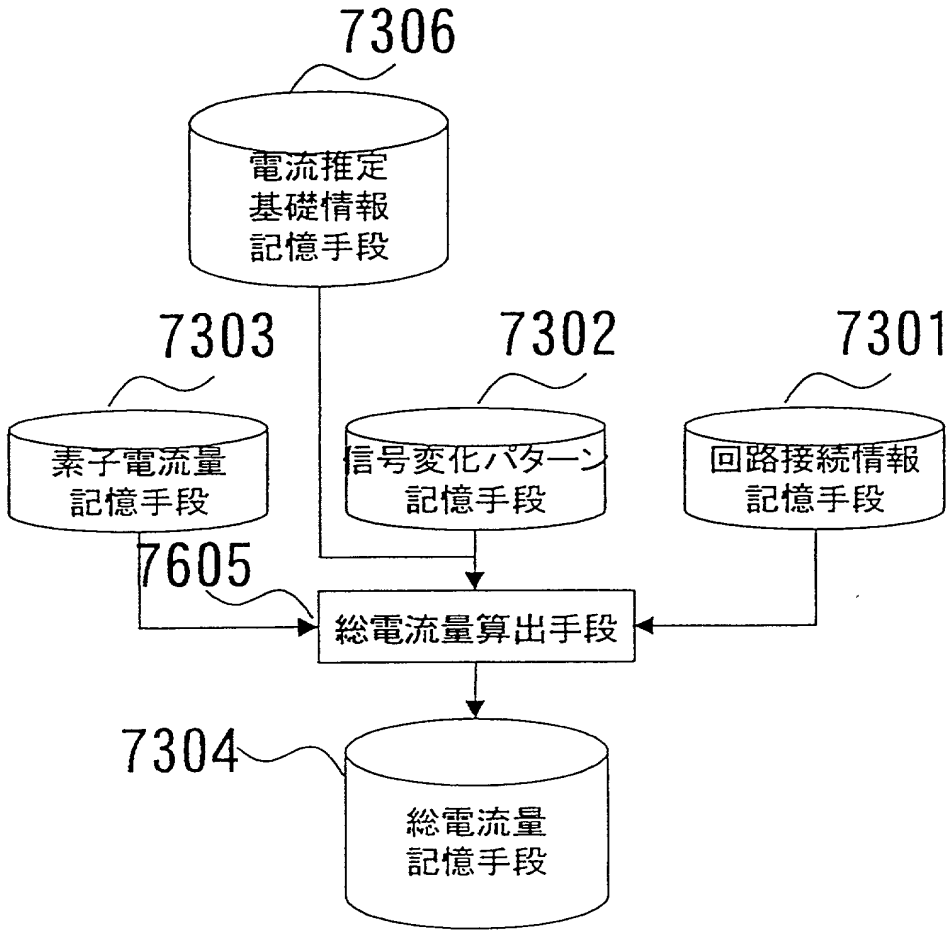


Fig. 57

フリップフロップFF

Y変化時貫通電流成分電流量	2mA	7401
Y変化時チャージ電流成分電流量	3mA	7402
CK変化時貫通電流成分電流量	1mA	7403
CK変化時チャージ電流成分電流量	1mA	7404

バッファBUF

Y変化時貫通電流成分電流量	0.5mA	7405
Y変化時チャージ電流成分電流量	0.5mA	7406

Fig. 58

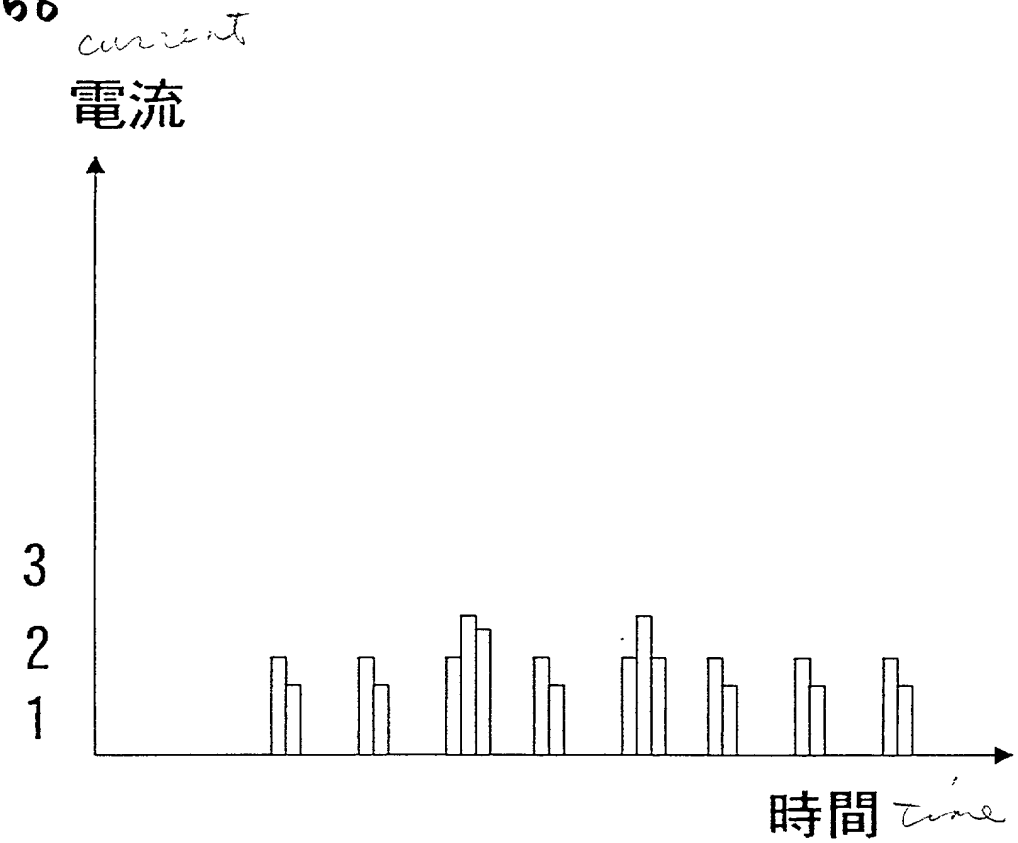

current
電流
3
2
1
時間
time

Fig. 59

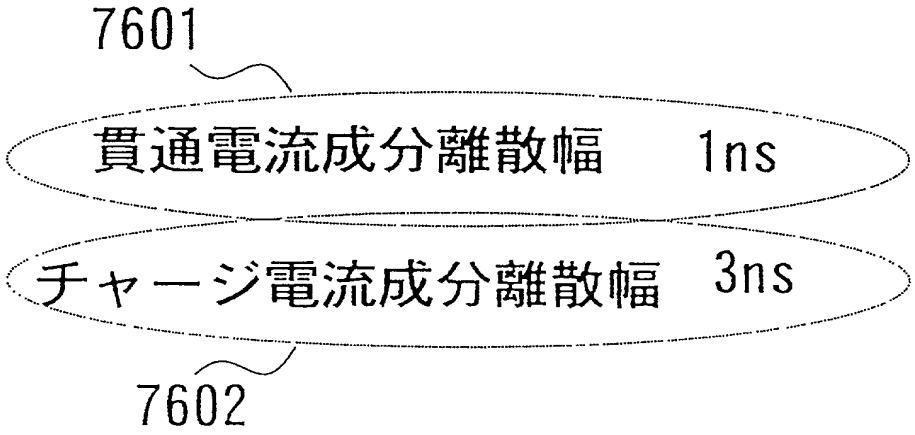
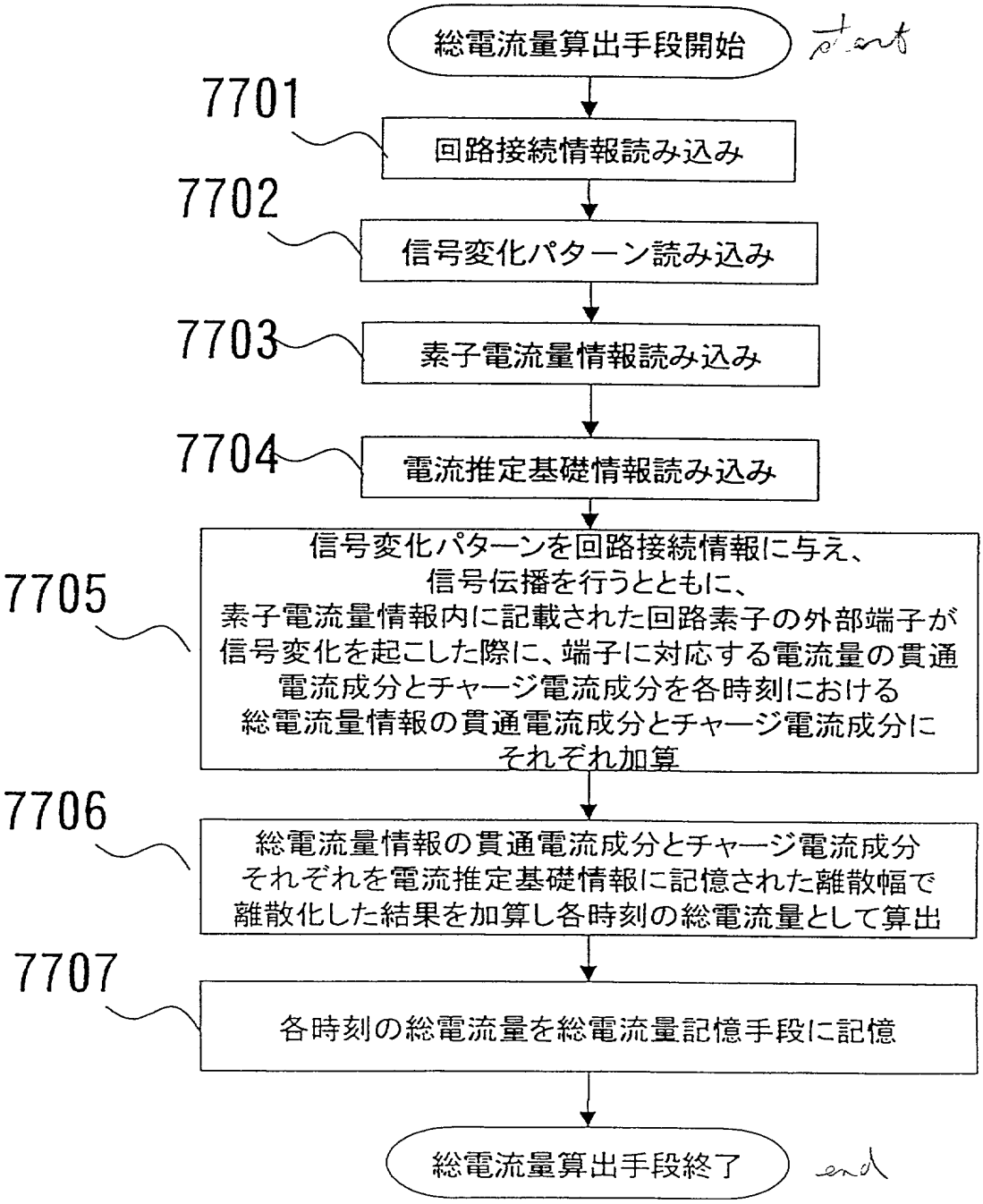

7601
貫通電流成分離散幅　1ns
チャージ電流成分離散幅　3ns
7602

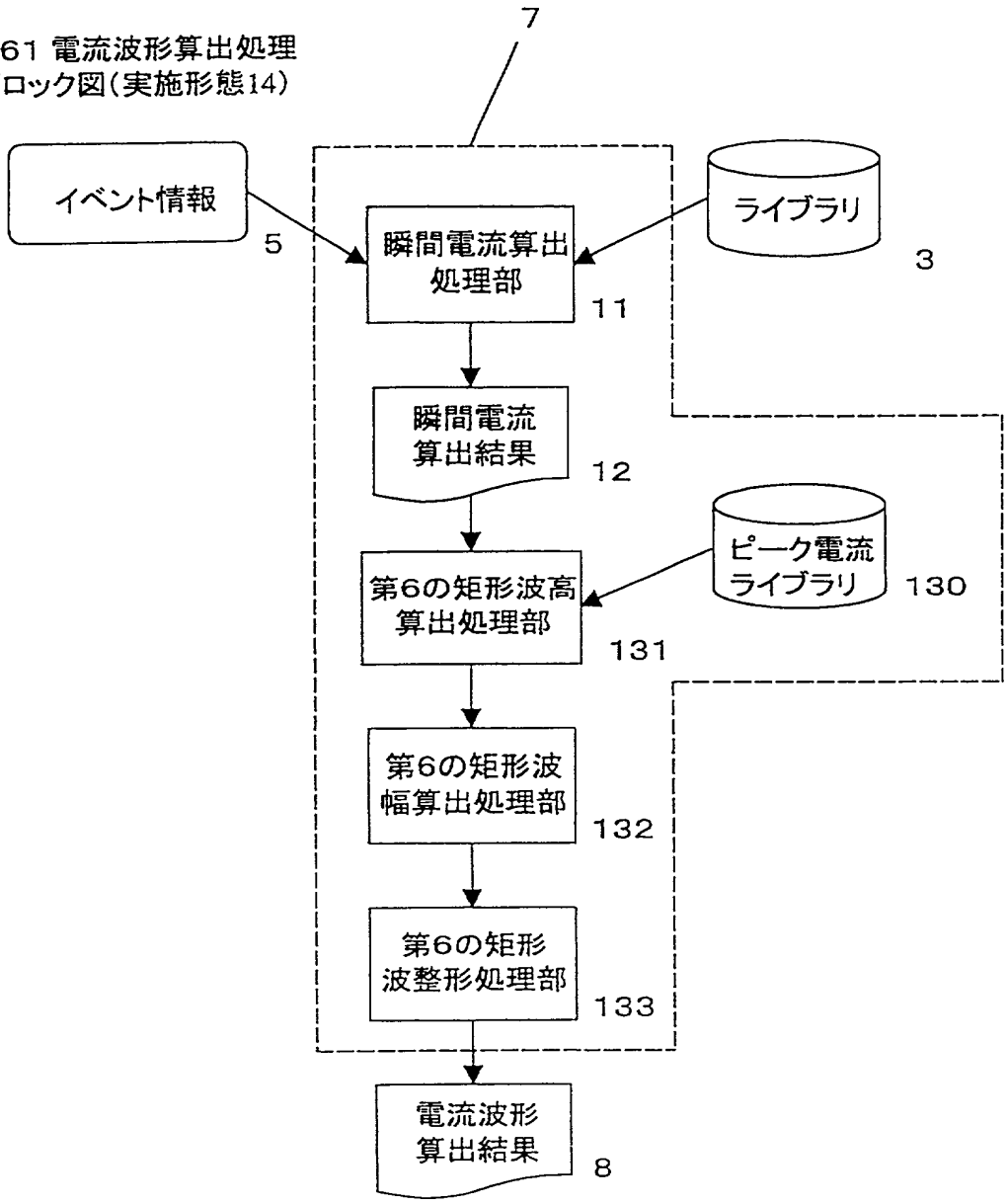
Fig. 60



0954502-030300

Fig. 61

図61 電流波形算出処理
ブロック図(実施形態14)



09054502-070700

Fig. 62

図62 第6の矩形波整形処理フロー図

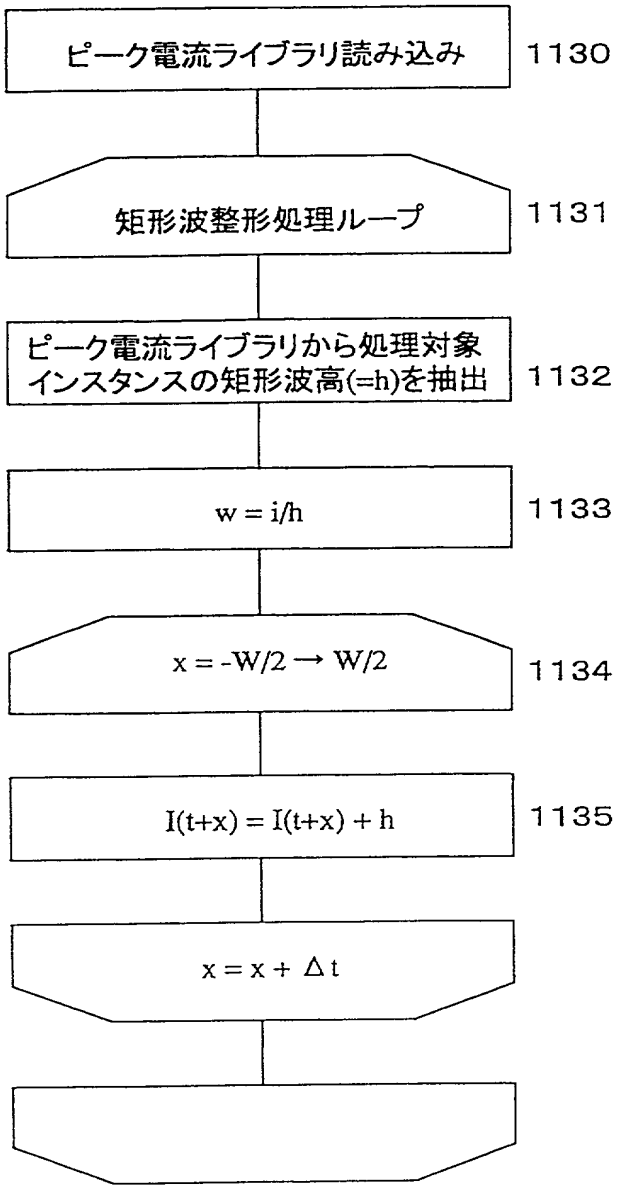
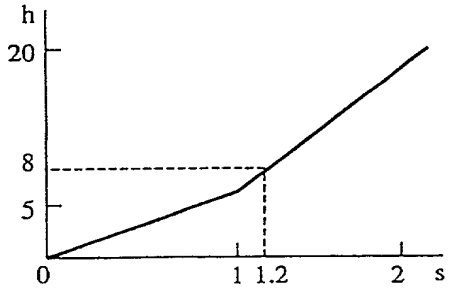


Fig. 63

図63 s - h テーブル

s	h
0	0
1	5
2	20



s = 1.2 の場合
(s1,h1)=(1,5)
(s2,h2)=(2,20)

$$h(s)=\frac{h2-h1}{s2-s1}(s-s1)+h1$$

h(1.2)=8

Fig. 64

図64 電流波形算出処理
ブロック図(実施形態15)

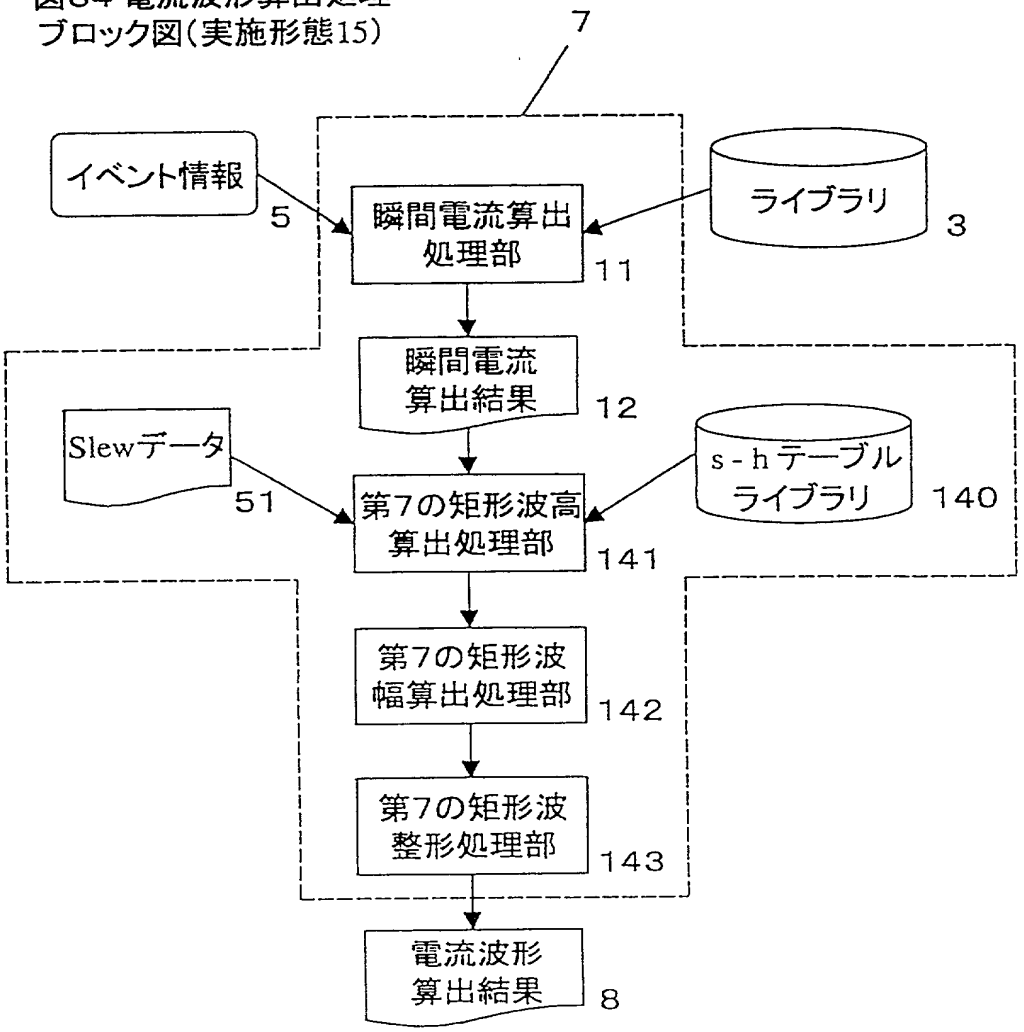


Fig. 65

図65 第7の矩形波整形処理フロー図

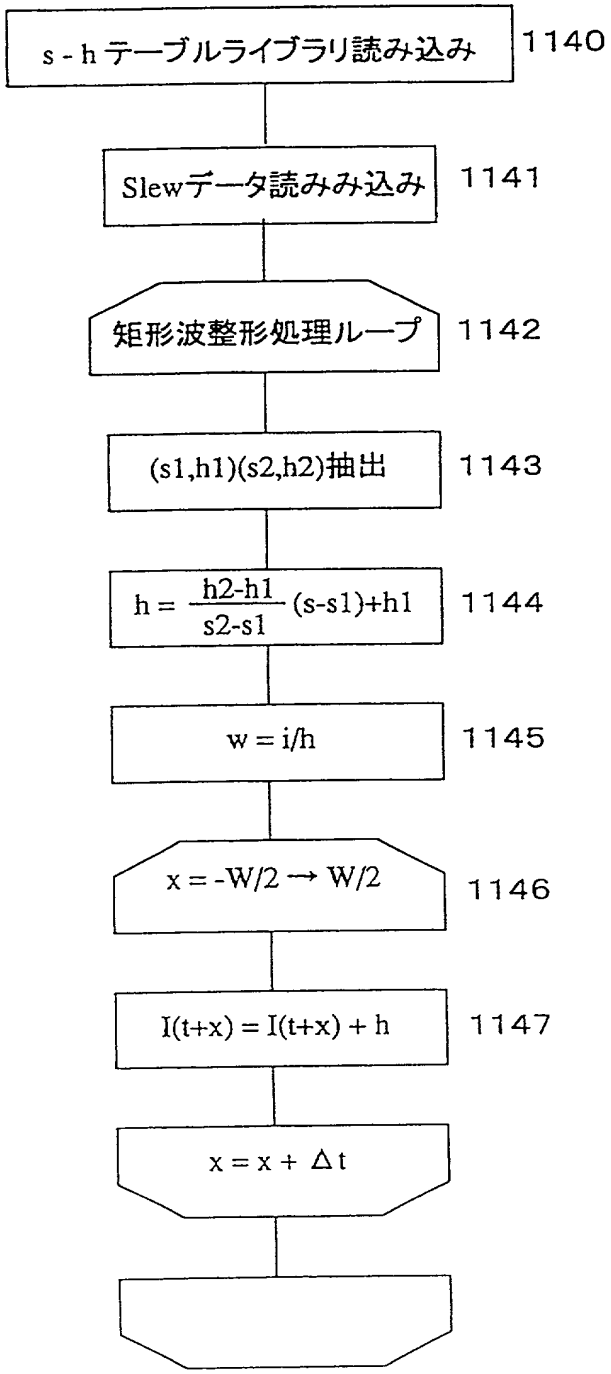
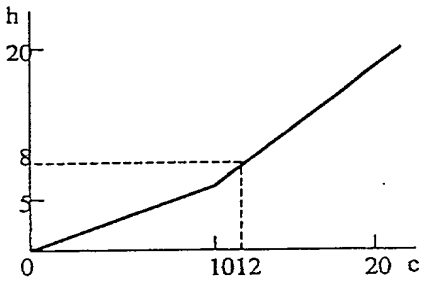


Fig. 66

図66 c - h テーブル

c	h
0	0
10	5
20	20



c＝12 の場合
(c1,h1)=(10,5)
(c2,h2)=(20,20)

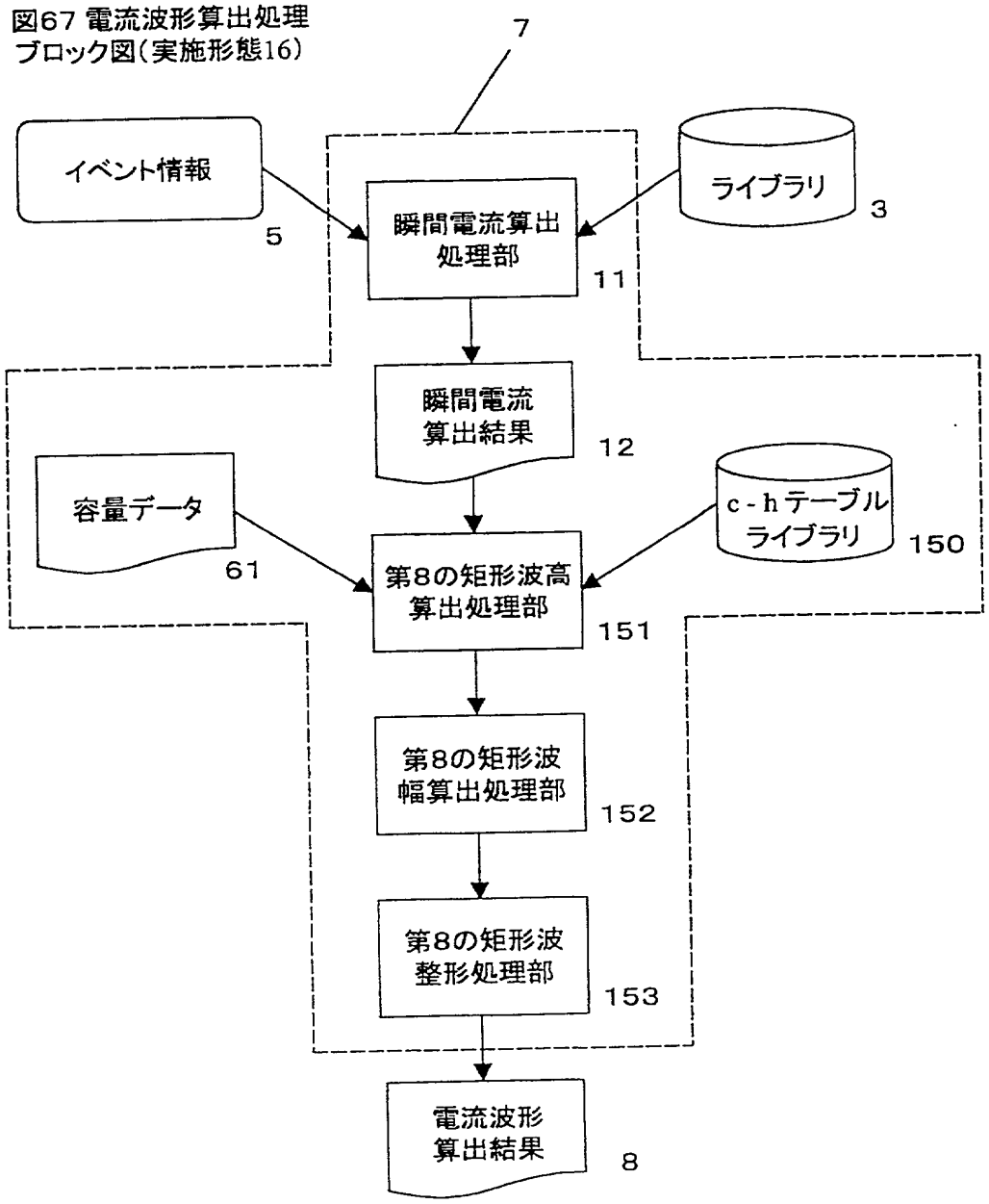
$$h(c)=\frac{h2-h1}{c2-c1}(c-c1)+h1$$

h(12)=8

0037610033

Fig. 67

図67 電流波形算出処理
ブロック図(実施形態16)



0537610033-050709

Fig. 68

図68 第8の矩形波整形処理フロー図

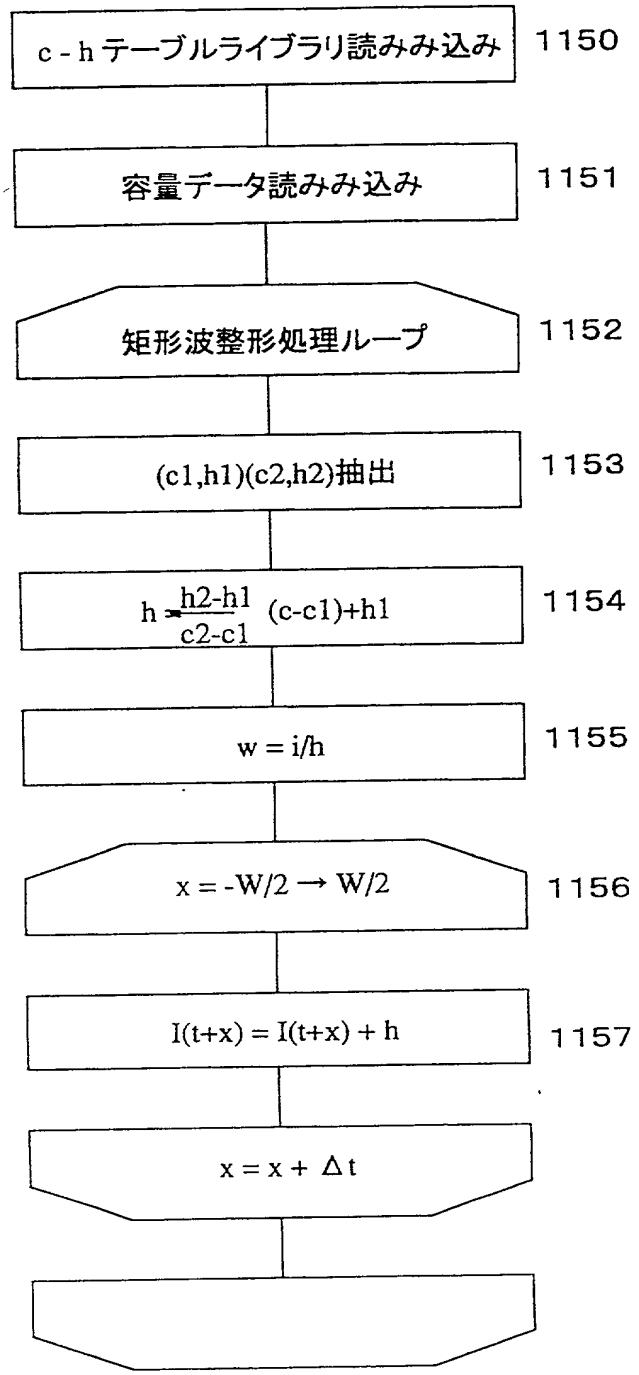


Fig. 69

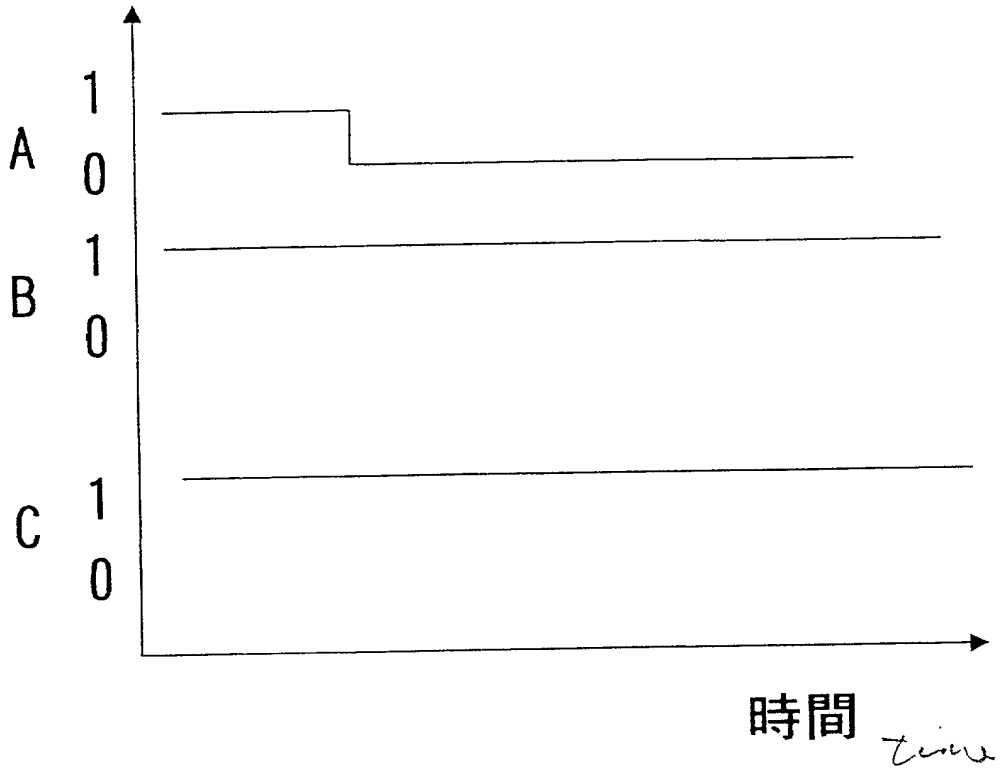


Fig. 70

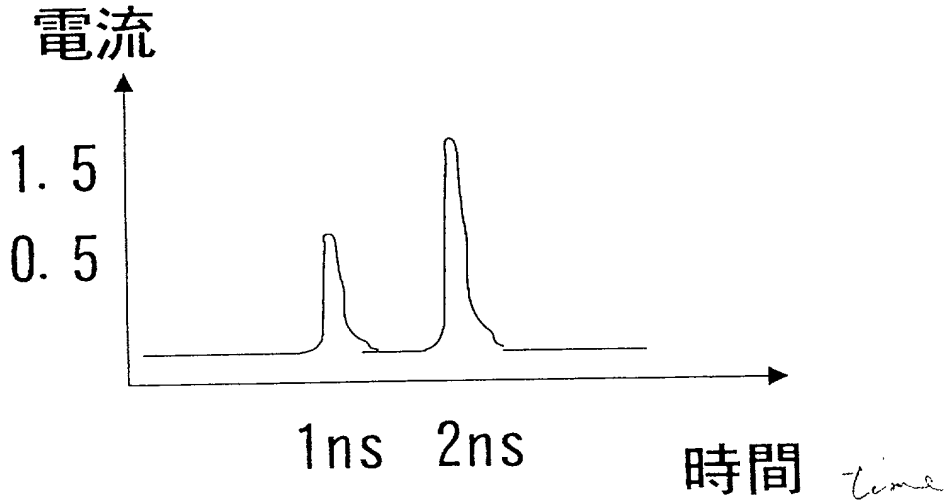


Fig. 71

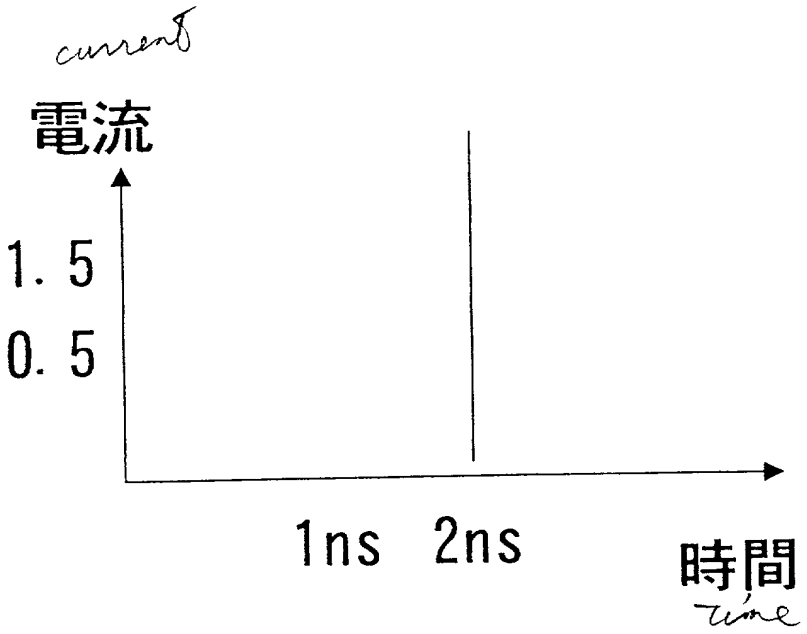

current
電流
1.5
0.5
1ns
2ns
時間
time

Fig. 72

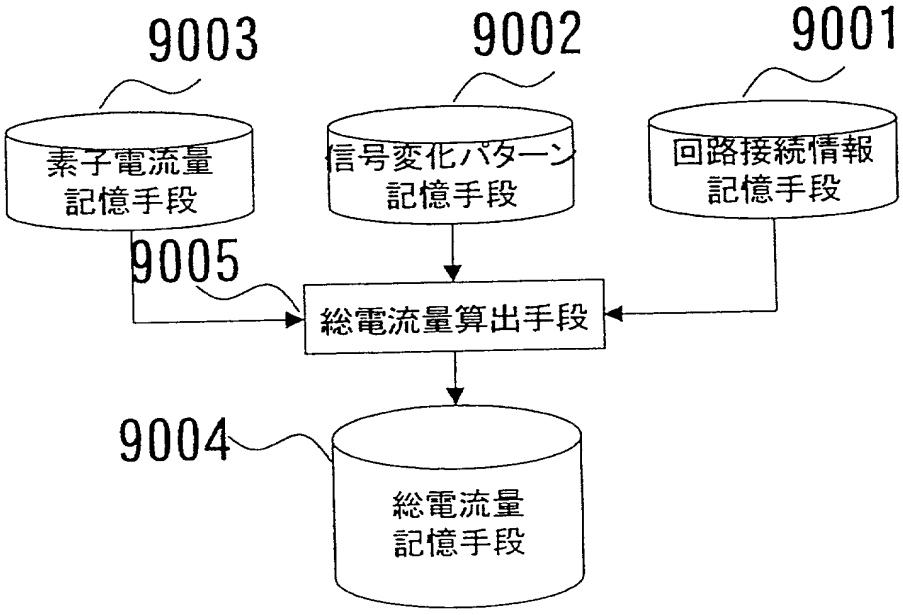

9003
9002
9001
素子電流量
記憶手段
信号変化パターン
記憶手段
回路接続情報
記憶手段
9005
総電流量算出手段
9004
総電流量
記憶手段

Fig. 73

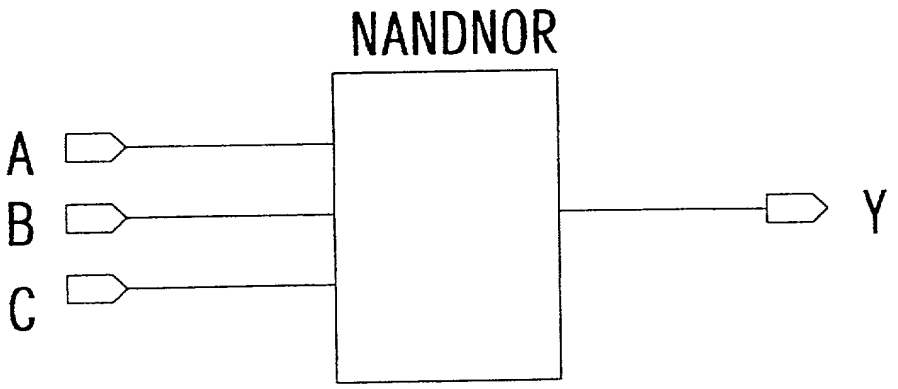


Fig. 74

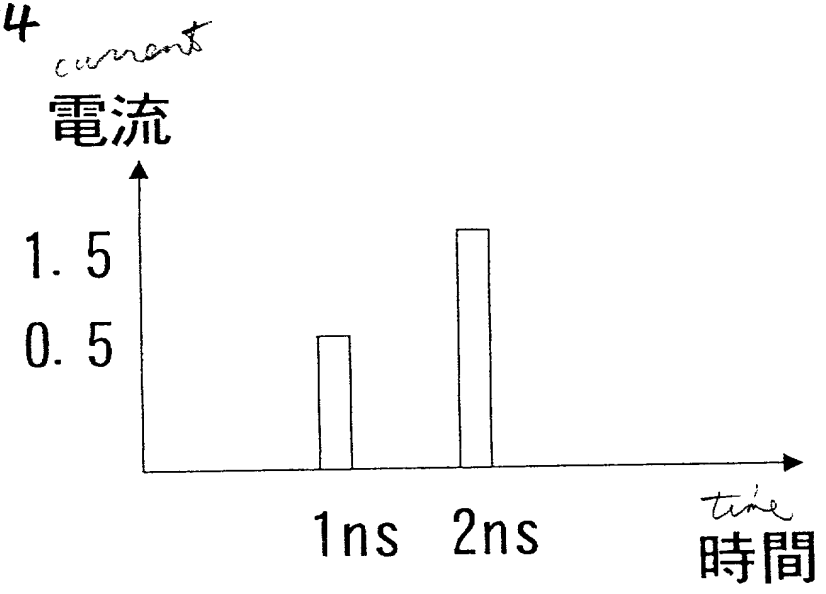


Fig. 75

NANDNOR

9301 変化ピン	9302 時間	9303 電流総量	9304 ピーク	
A	1ns	1mA	0.5mA	9305
A	2ns	3mA	1.5mA	
B	1ns	1mA	0.5mA	9306
B	2ns	3mA	1.5mA	
C	1ns	3mA	1.5mA	9307

0956252582-970700

Fig. 76

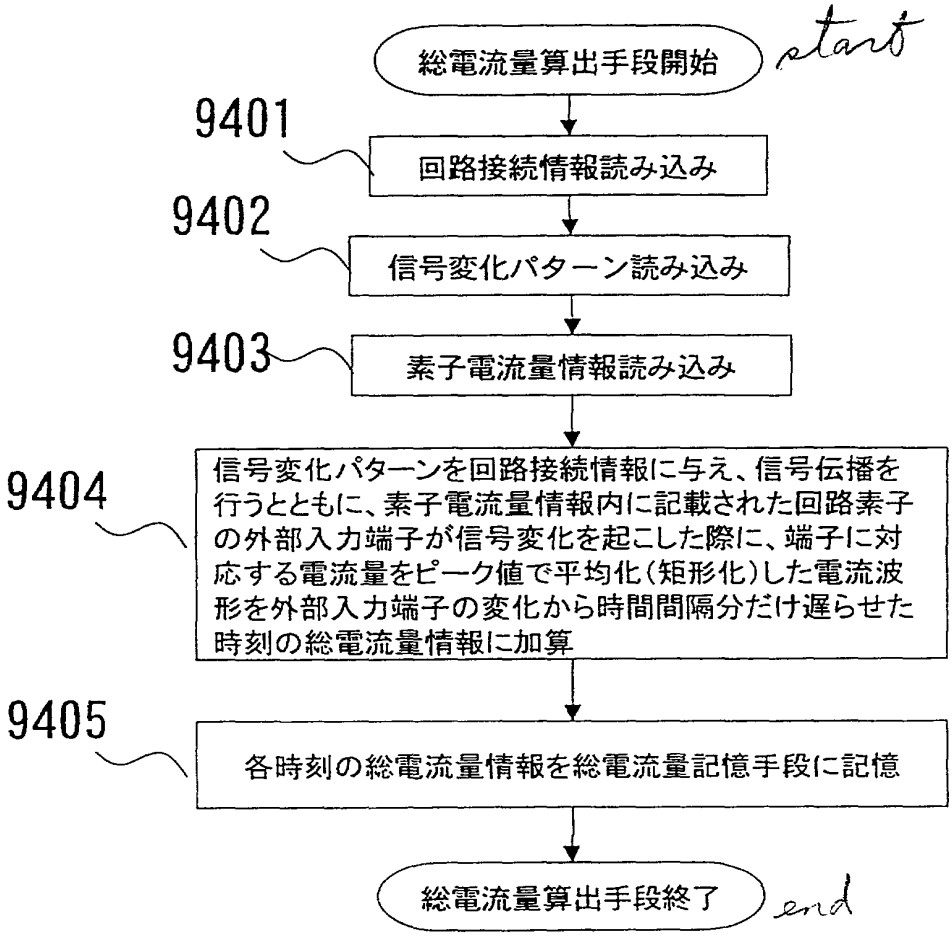

総電流量算出手段開始
start
9401
回路接続情報読み込み
9402
信号変化パターン読み込み
9403
素子電流量情報読み込み
9404
信号変化パターンを回路接続情報に与え、信号伝播を行うとともに、素子電流量情報内に記載された回路素子の外部入力端子が信号変化を起こした際に、端子に対応する電流量をピーク値で平均化（矩形化）した電流波形を外部入力端子の変化から時間間隔分だけ遅らせた時刻の総電流量情報に加算
9405
各時刻の総電流量情報を総電流量記憶手段に記憶
総電流量算出手段終了
end

Fig. 77

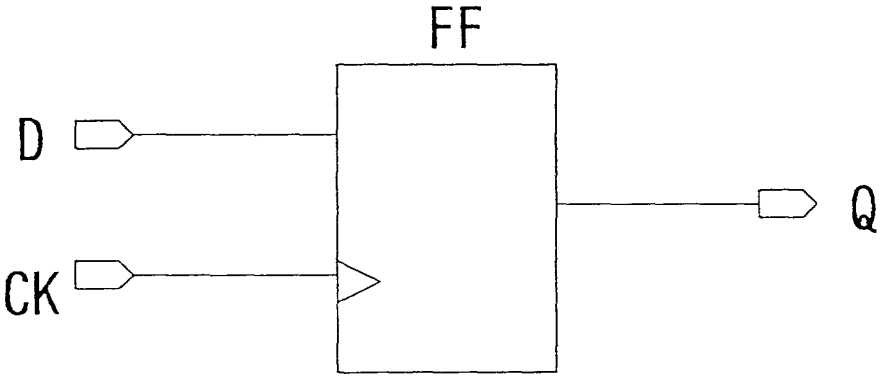

FF
D
CK
Q

Fig. 78

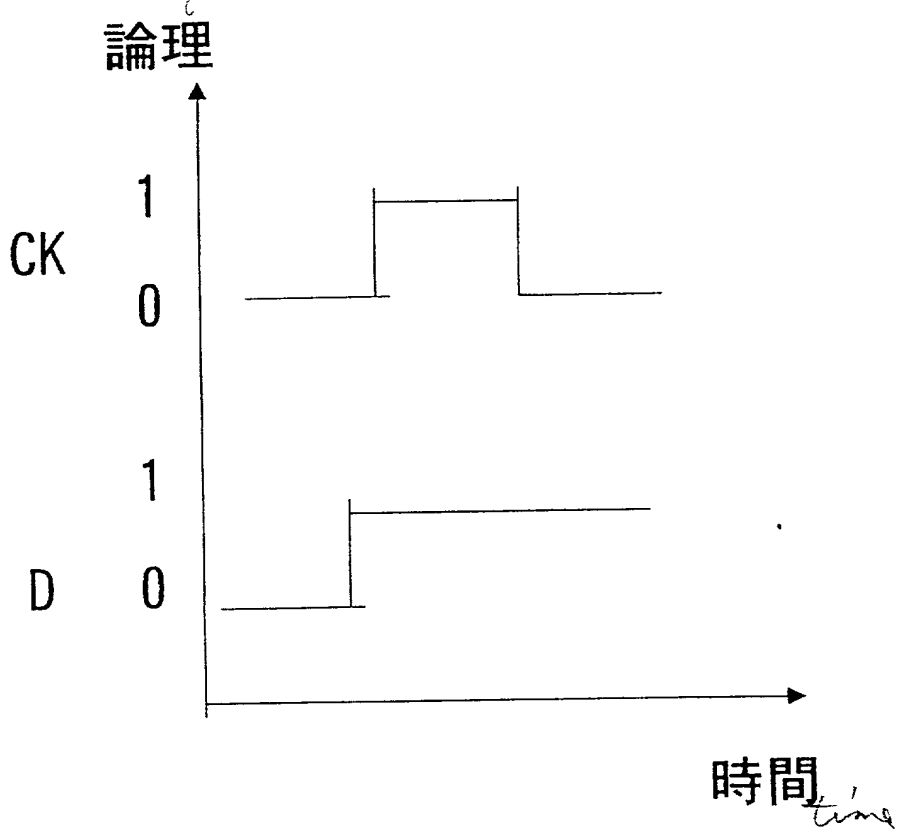
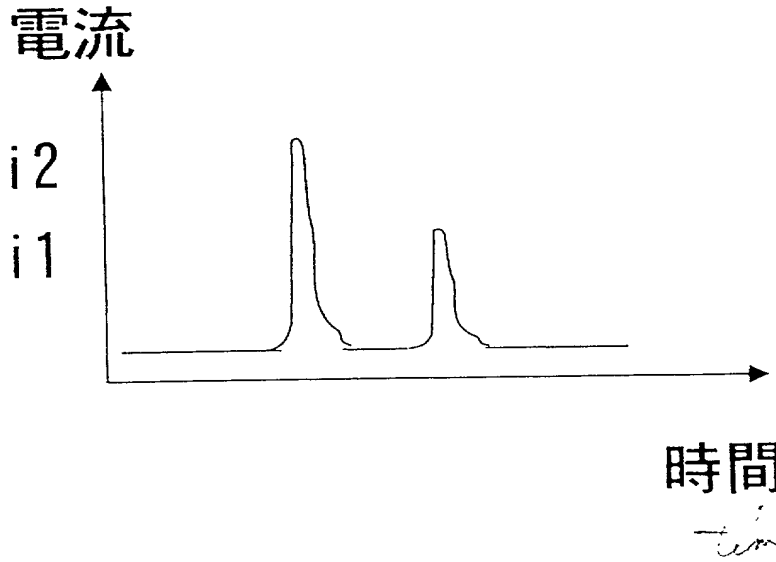


Fig. 79



DOCKET.NAVIGO

Fig. 80.

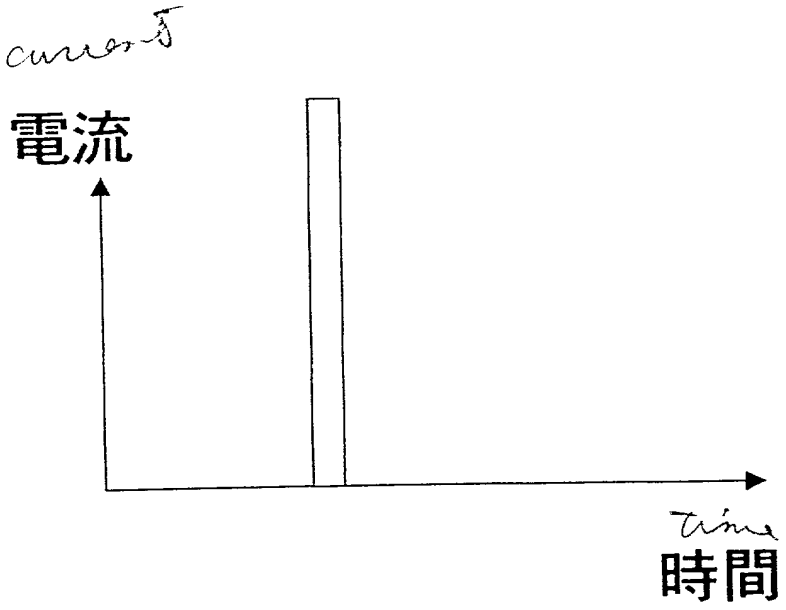
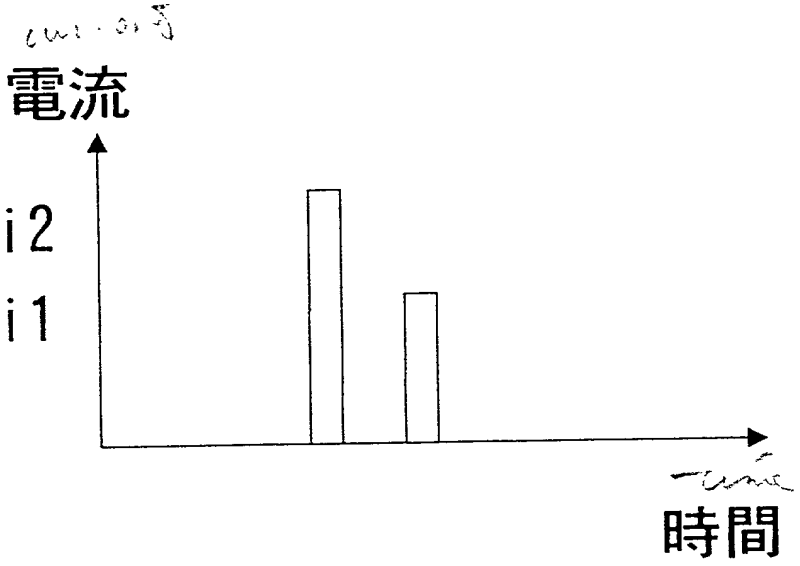


Fig. 81

FF	エッジ	電流	ピーク値
	rise	15mA	7.5mA
	fall	5mA	2.5mA

9901　9902

Fig. 82



0950500-0000

Fig. 83

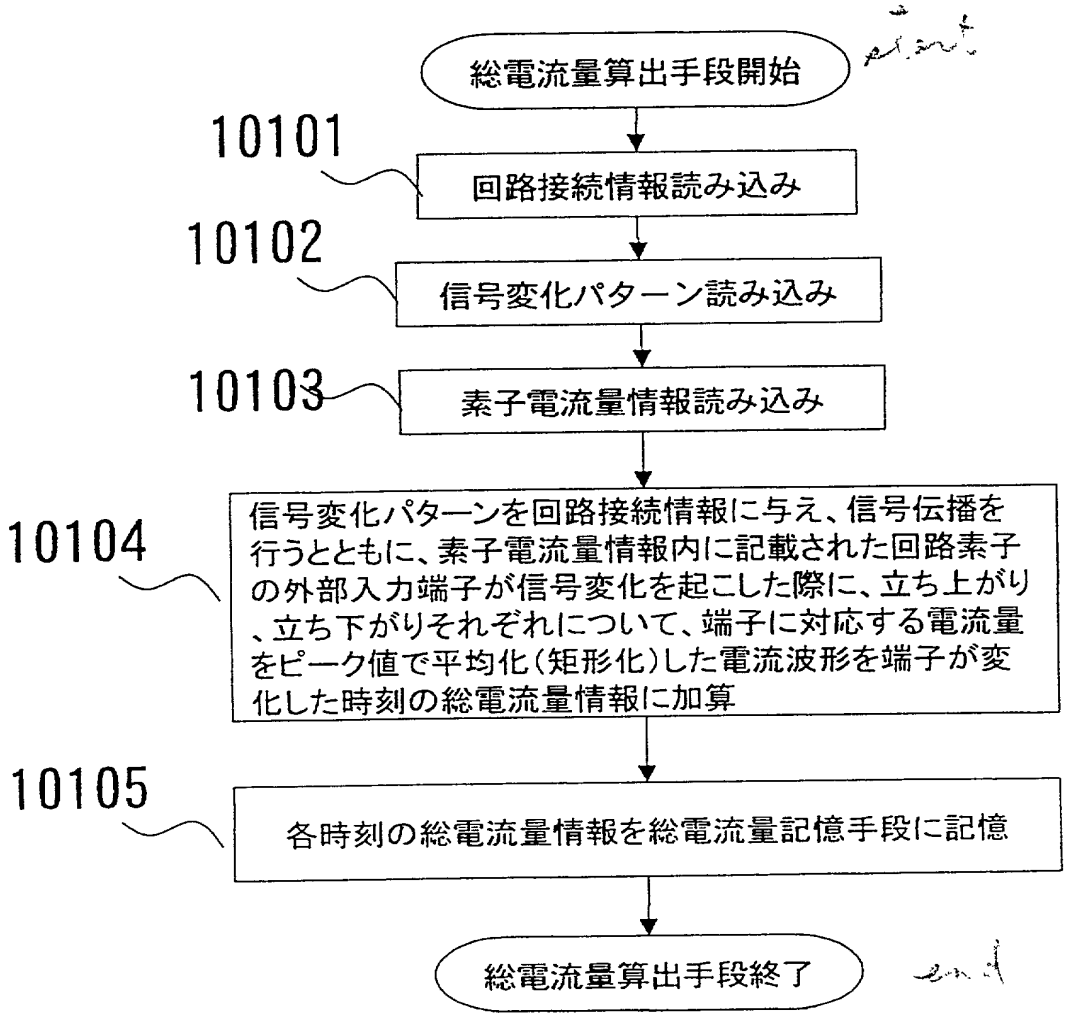

総電流量算出手段開始
10101
回路接続情報読み込み
10102
信号変化パターン読み込み
10103
素子電流量情報読み込み
10104
信号変化パターンを回路接続情報に与え、信号伝播を行うとともに、素子電流量情報内に記載された回路素子の外部入力端子が信号変化を起こした際に、立ち上がり、立ち下がりそれぞれについて、端子に対応する電流量をピーク値で平均化（矩形化）した電流波形を端子が変化した時刻の総電流量情報に加算
10105
各時刻の総電流量情報を総電流量記憶手段に記憶
総電流量算出手段終了

Fig. 84

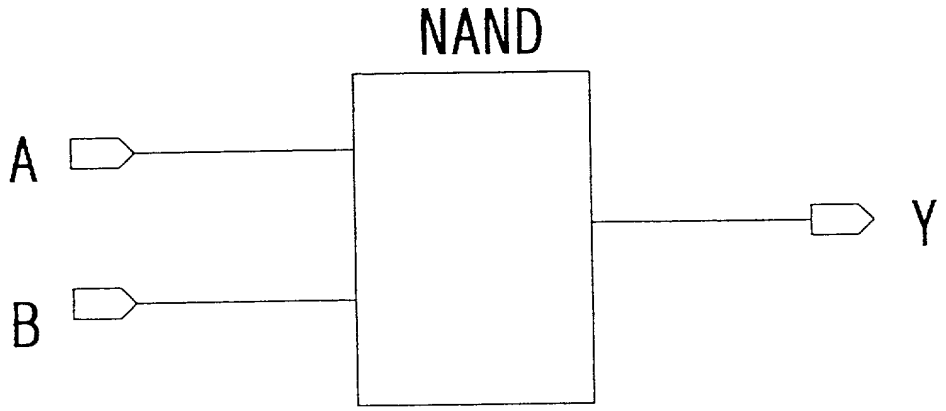

NAND
A
B
Y

Fig. 85

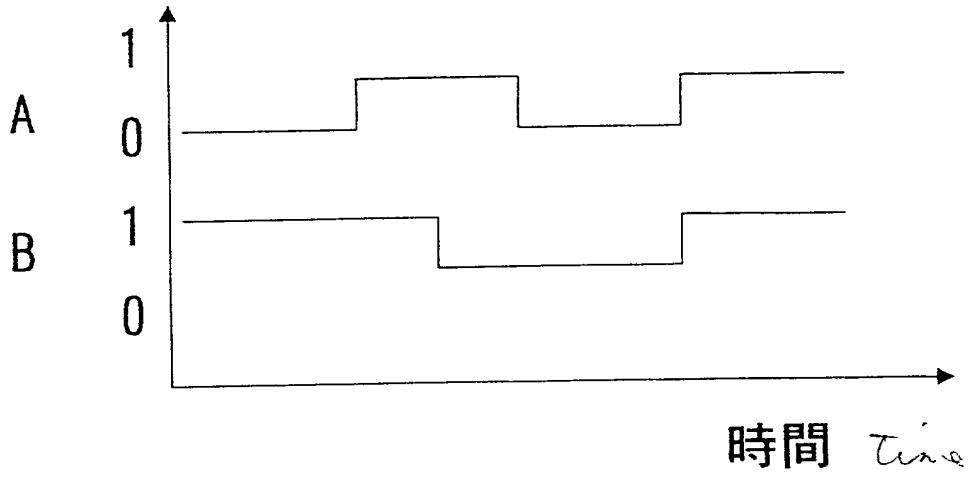
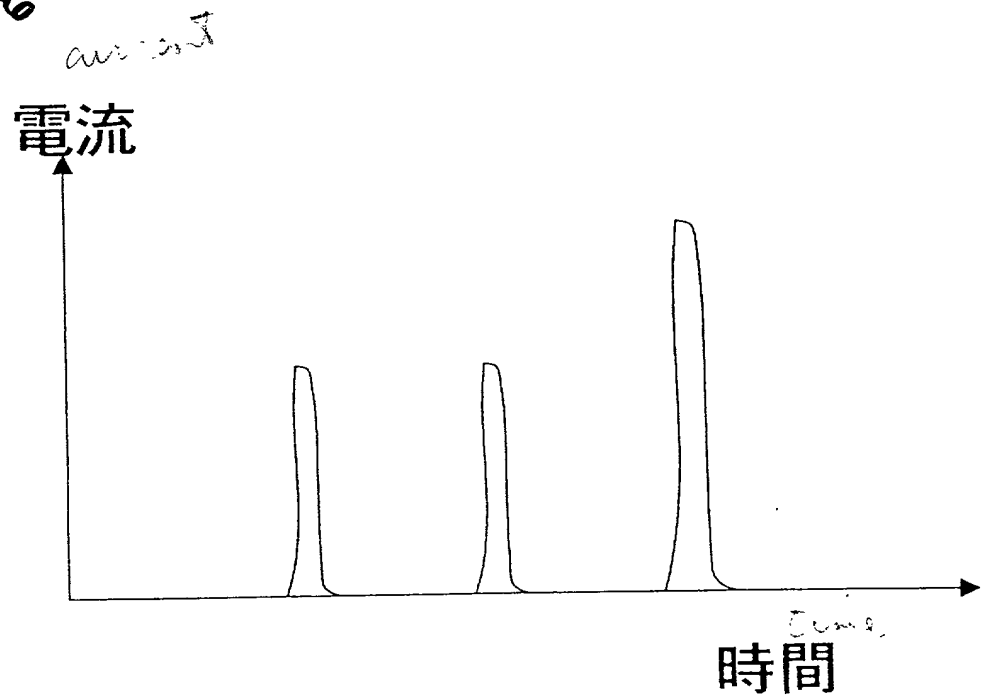
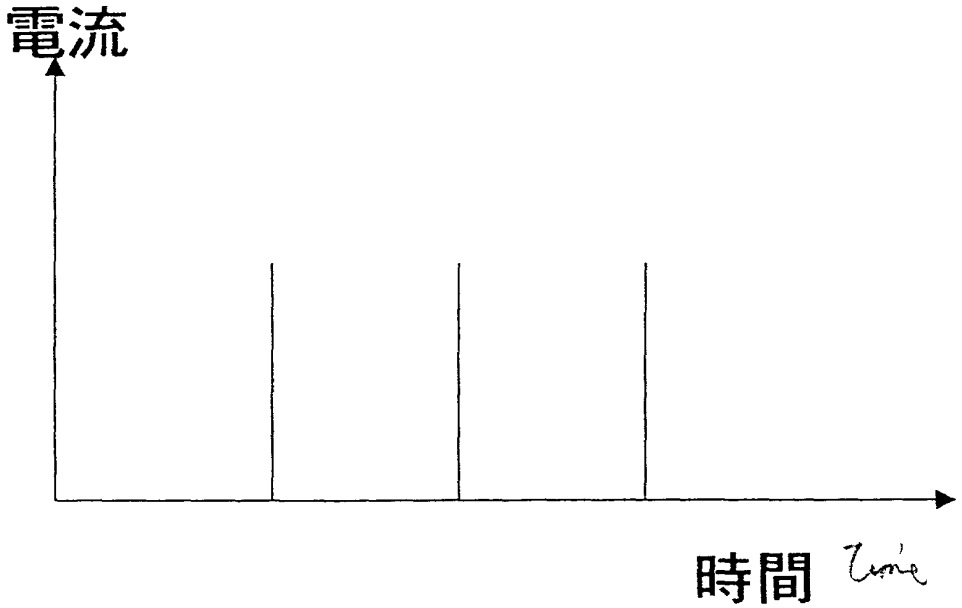


Fig. 86



0950-0950-0950-0950

Fig. 87

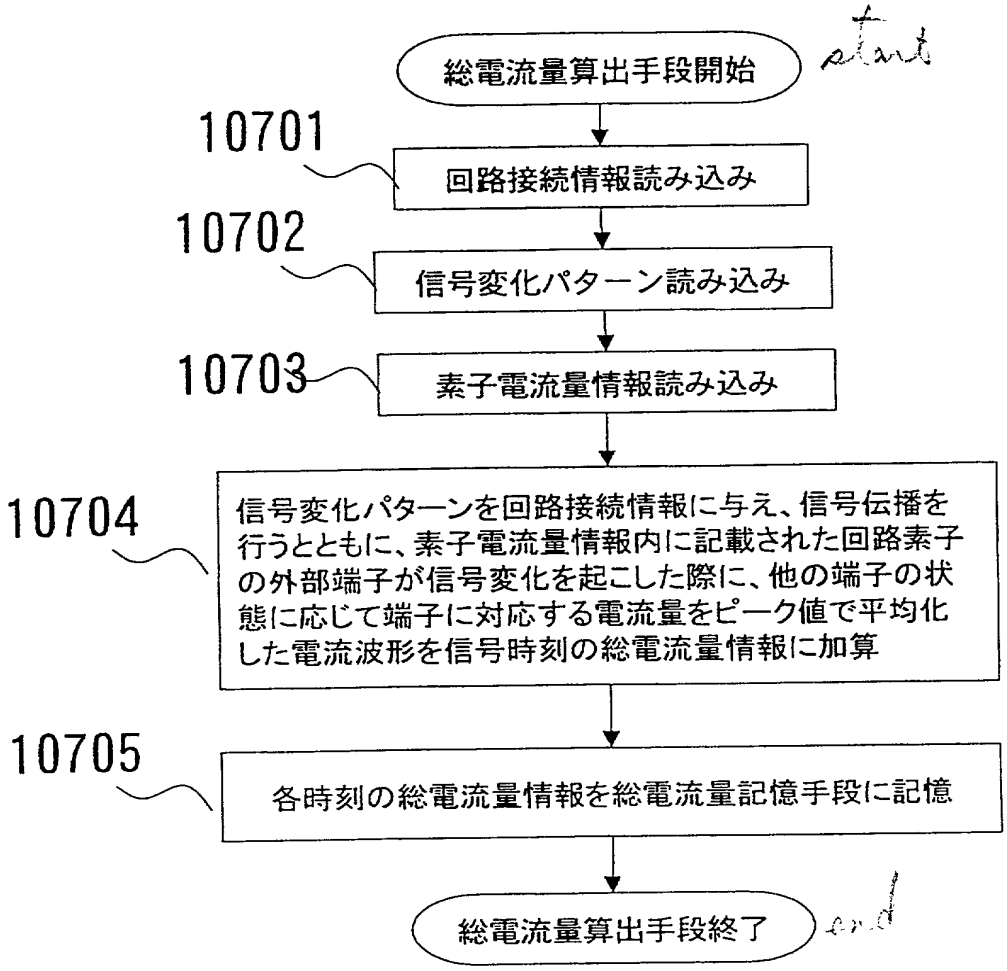


論理和否定 NAND Y端子　10601

A=1, B=0→1時の電流総量	3mA
A=1, B=0→1時のピーク値	1mA
A=1, B=1→0時の電流総量	3mA
A=1, B=1→0時のピーク値	1mA
B=1, A=0→1時の電流総量	3mA
B=1, A=0→1時のピーク値	1mA
B=1, A=1→0時の電流総量	3mA
B=1, A=1→0時のピーク値	1mA
A=0→1, B=0→1時の電流総量	4mA
A=0→1, B=0→1時のピーク値	1.5mA
A=1→0, B=1→0時の電流総量	4mA
A=1→0, B=1→0時のピーク値	1.5mA

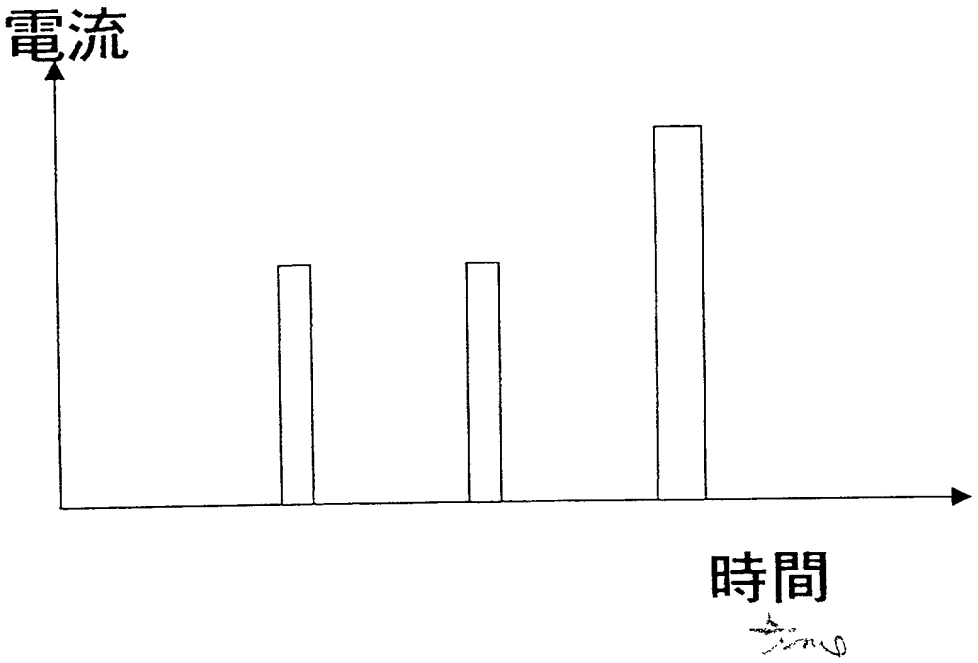
0961-N5820-0700

Fig 89



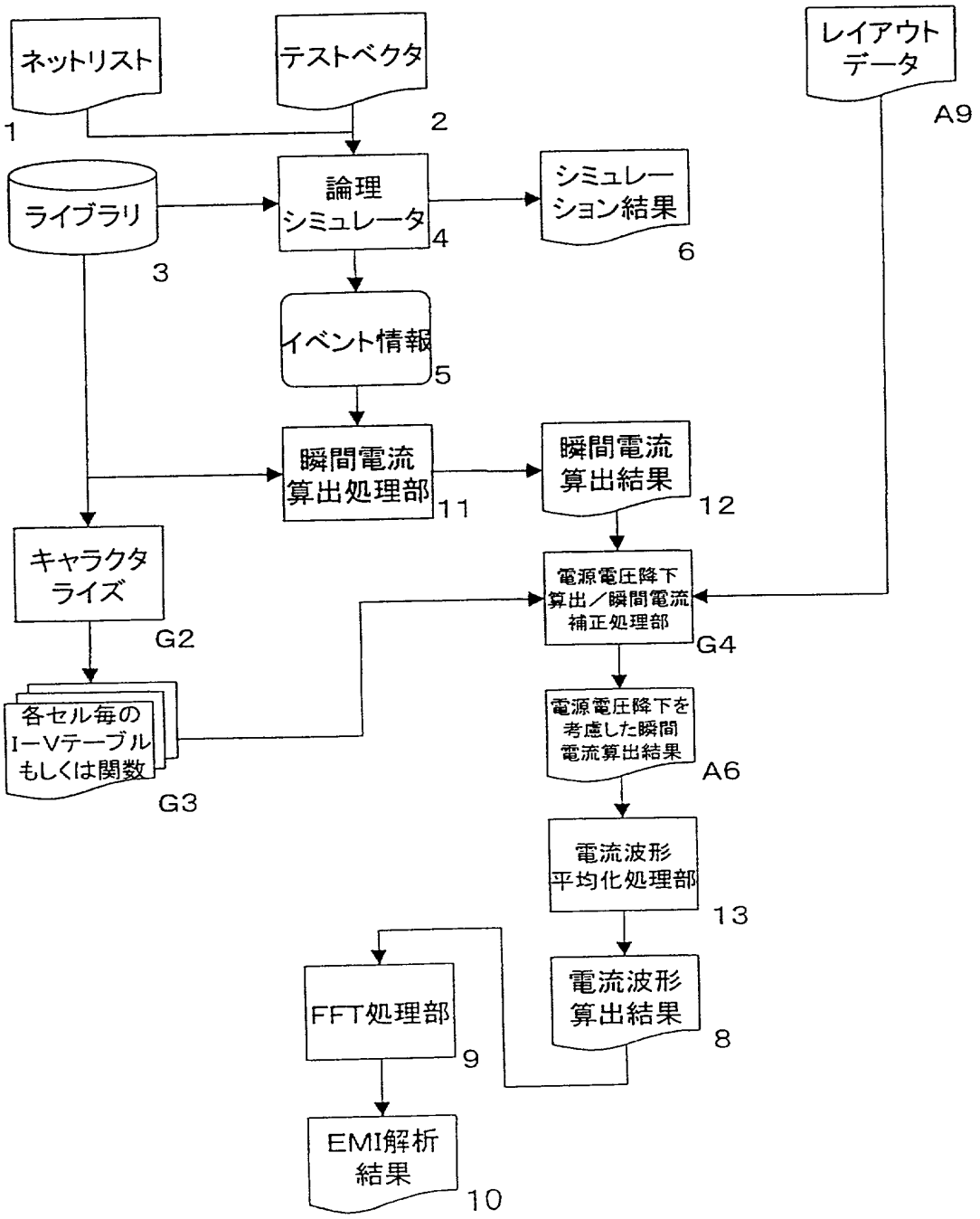
0950-0000-0000

Fig. 90



09705125.050

Fig. 91



DOCUMENT-0000000

Fig. 92

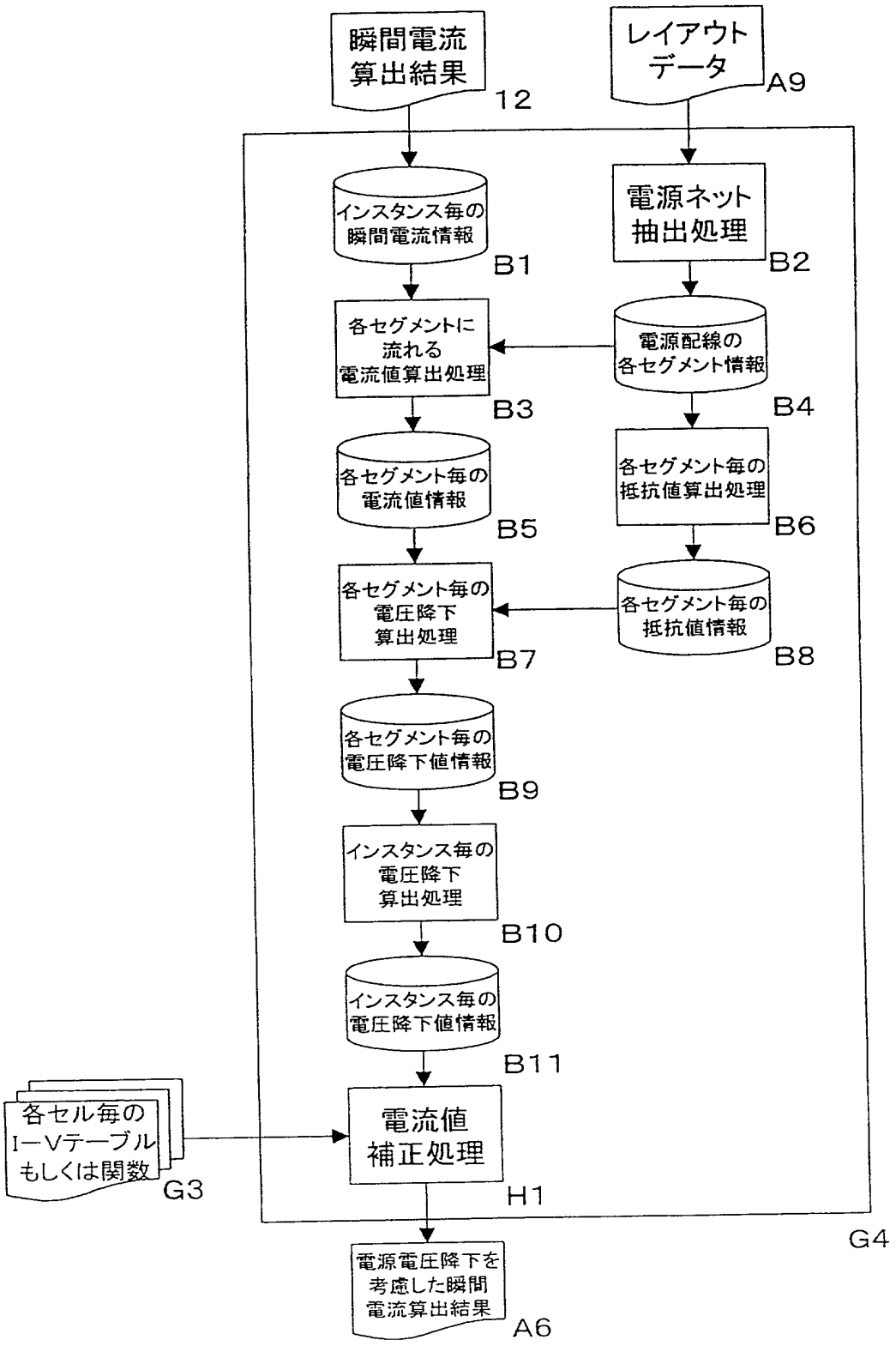

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補正処理
H1
G4
電源電圧降下を
考慮した瞬間
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Fig. 93

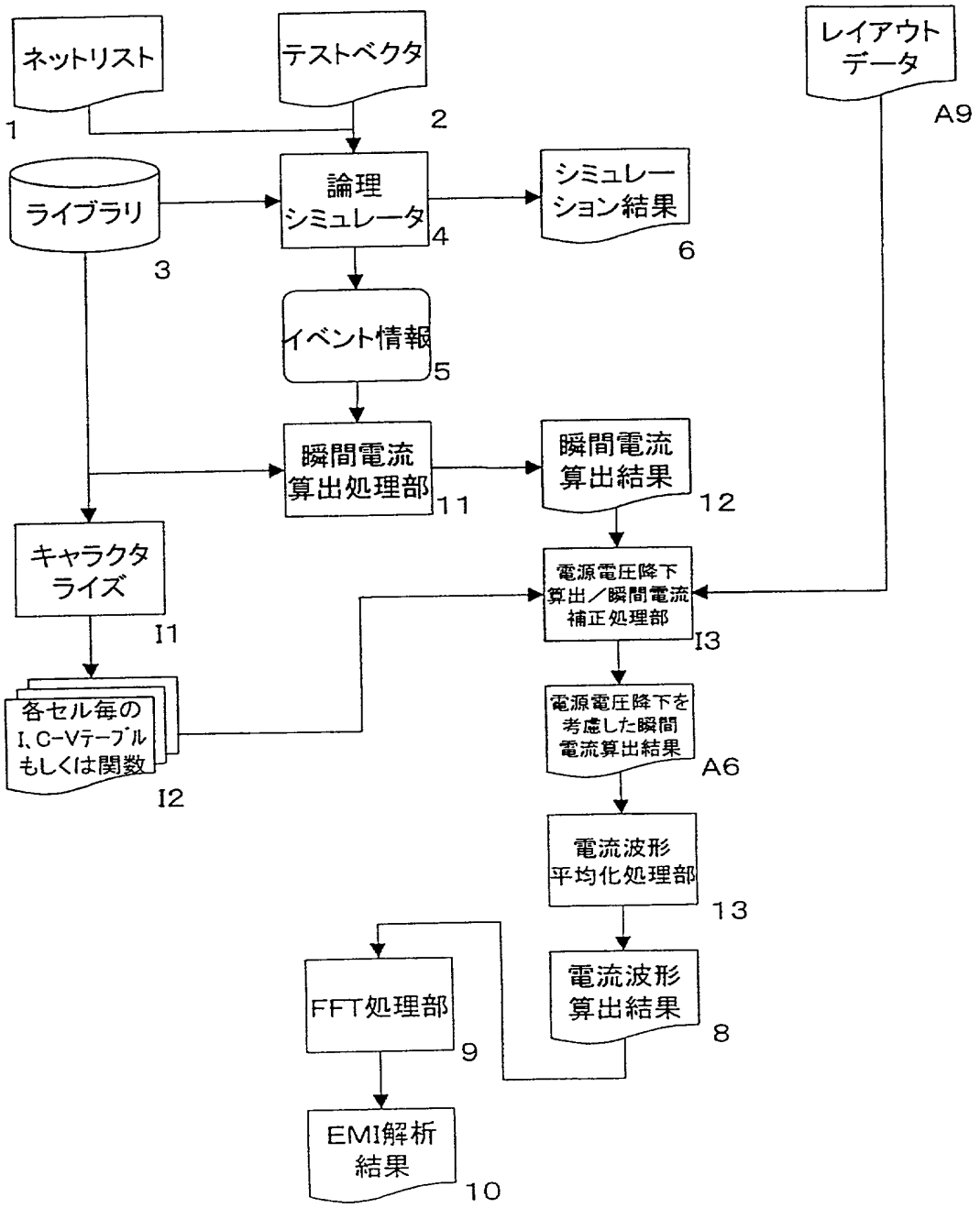

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13
FFT処理部
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EMI解析結果
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Fig.04

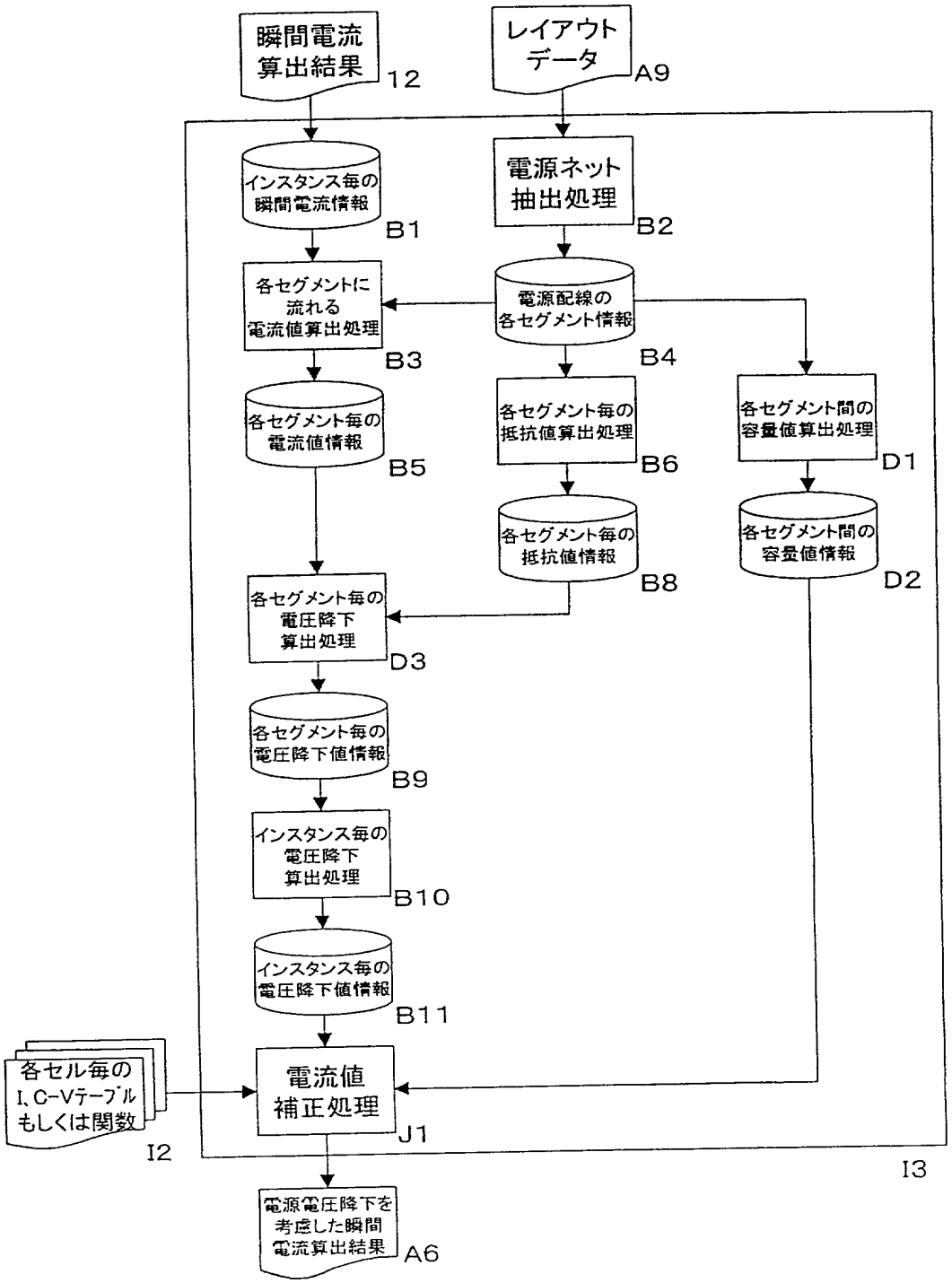

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Fig. 95

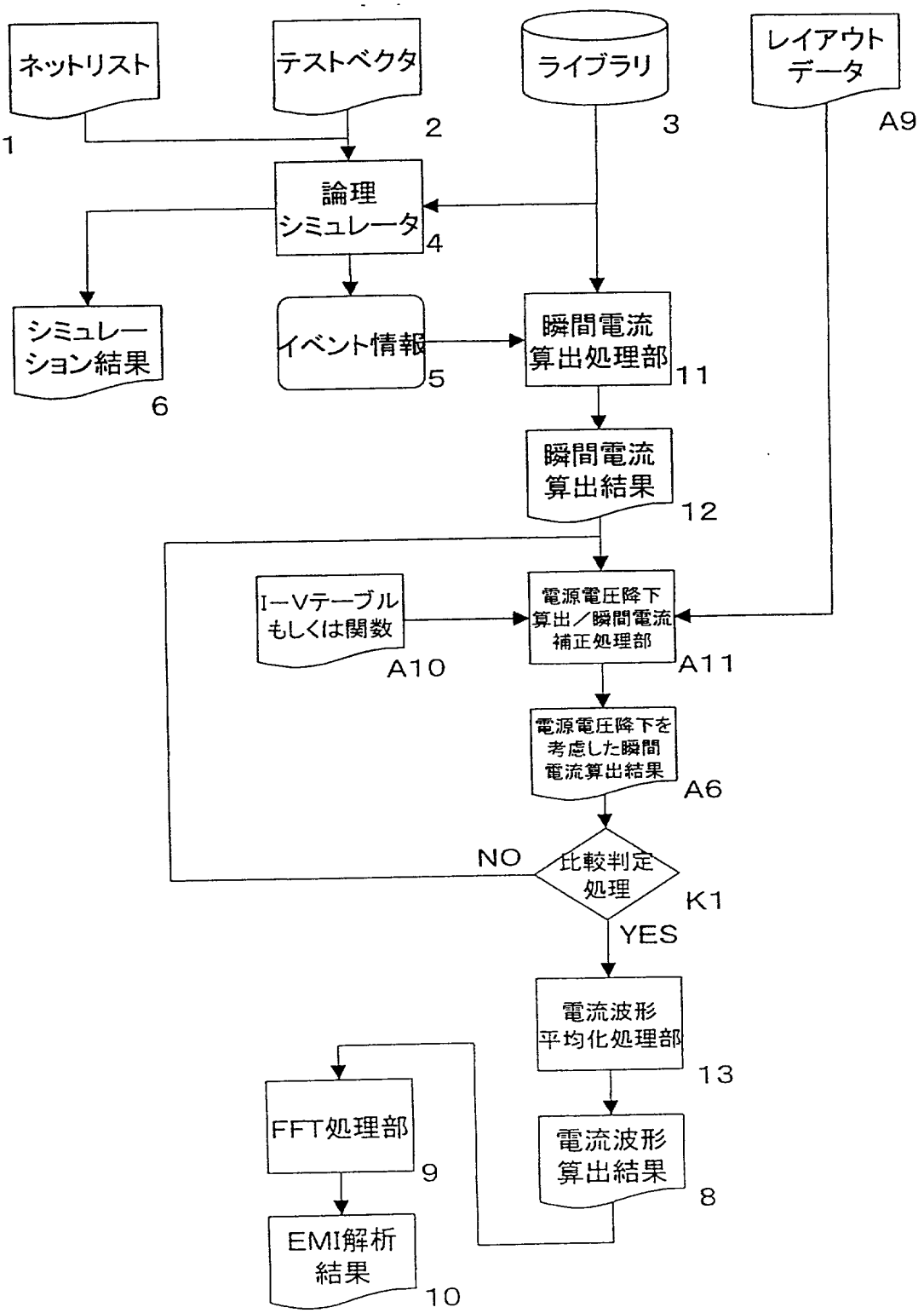
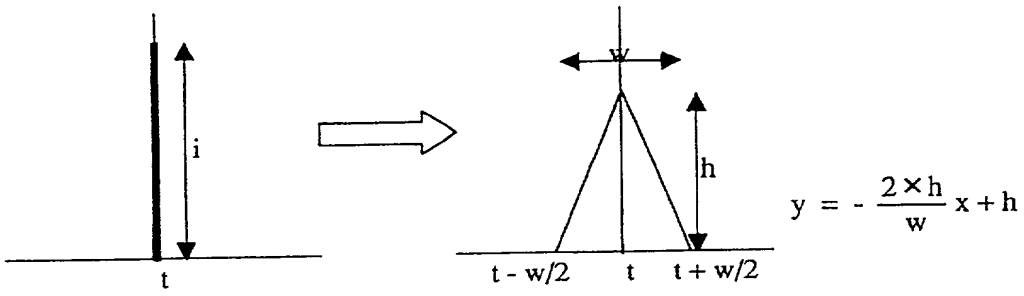

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Fig. 96

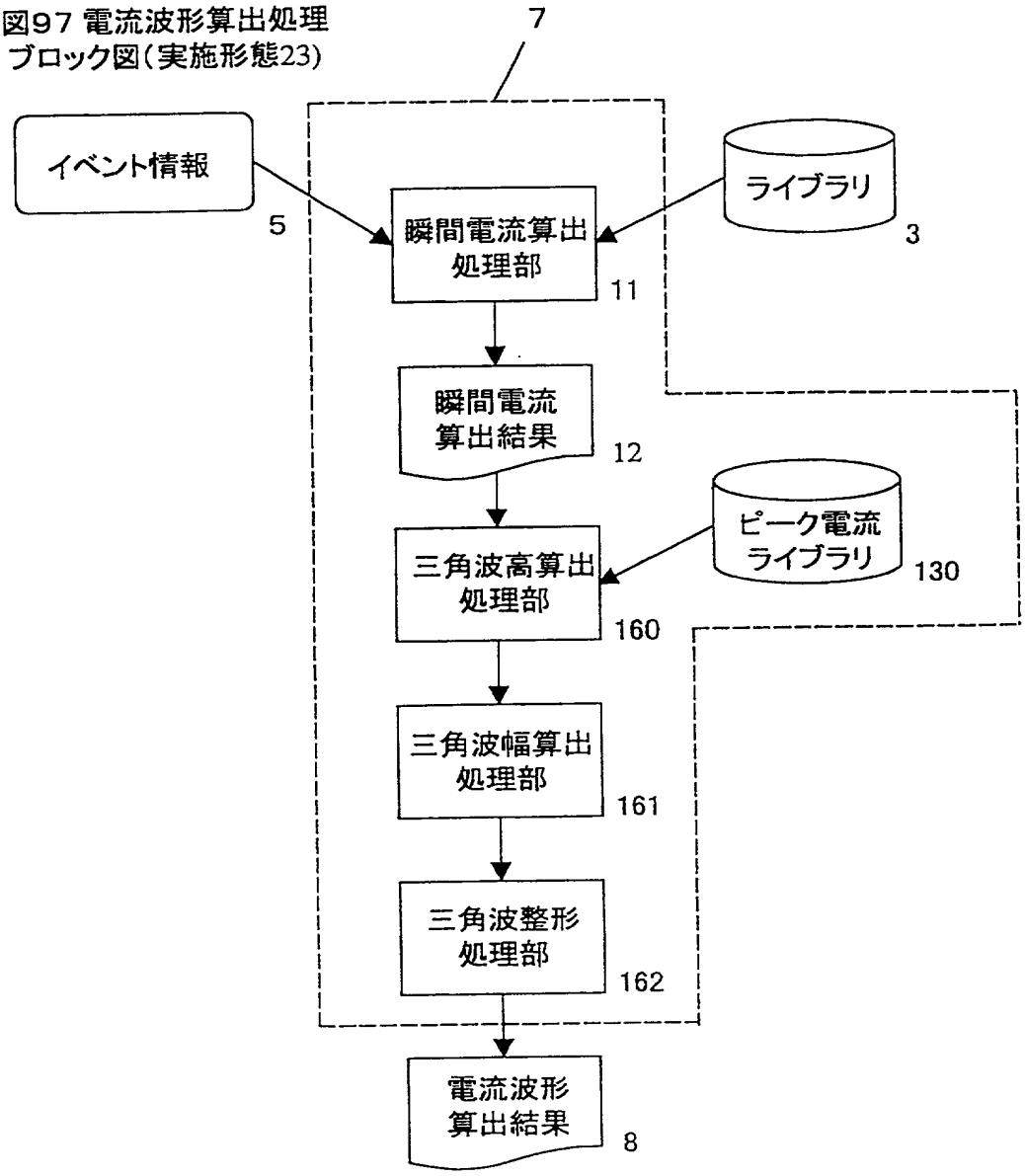
図96 三角波モデル(実施形態23)



0503761003300

Fig. 97

図97 電流波形算出処理
ブロック図(実施形態23)



0950538-090900

Fig. 98

図98 三角波整形処理フロー図

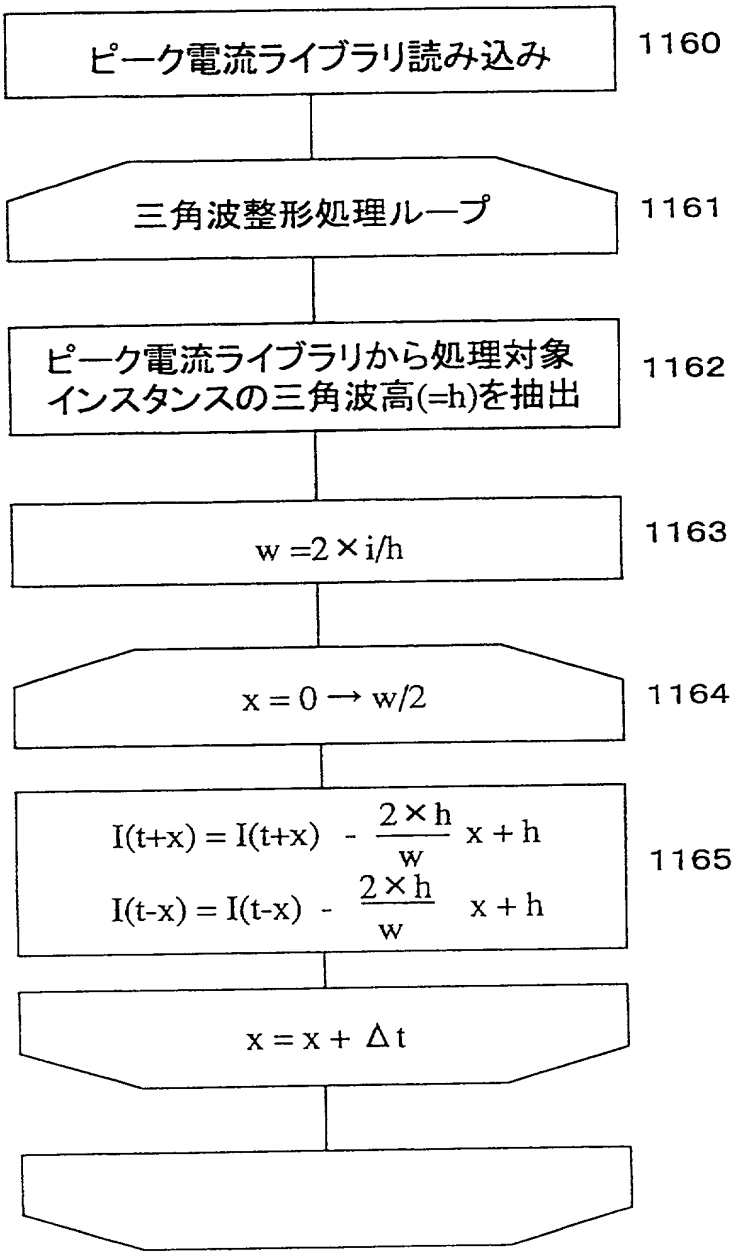
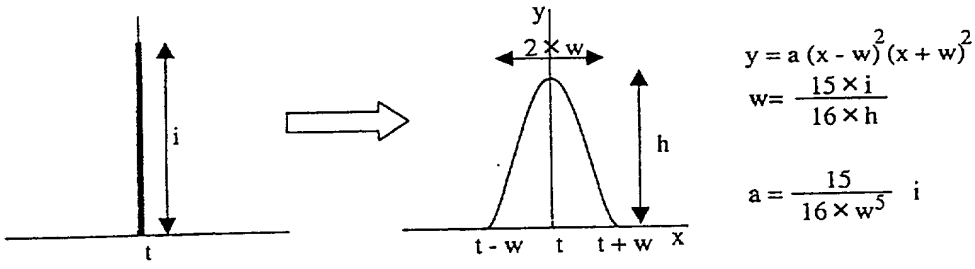


Fig.99

図99 複数次関数モデル(実施形態24)



$$y = a\,(x - w)^2 (x + w)^2$$

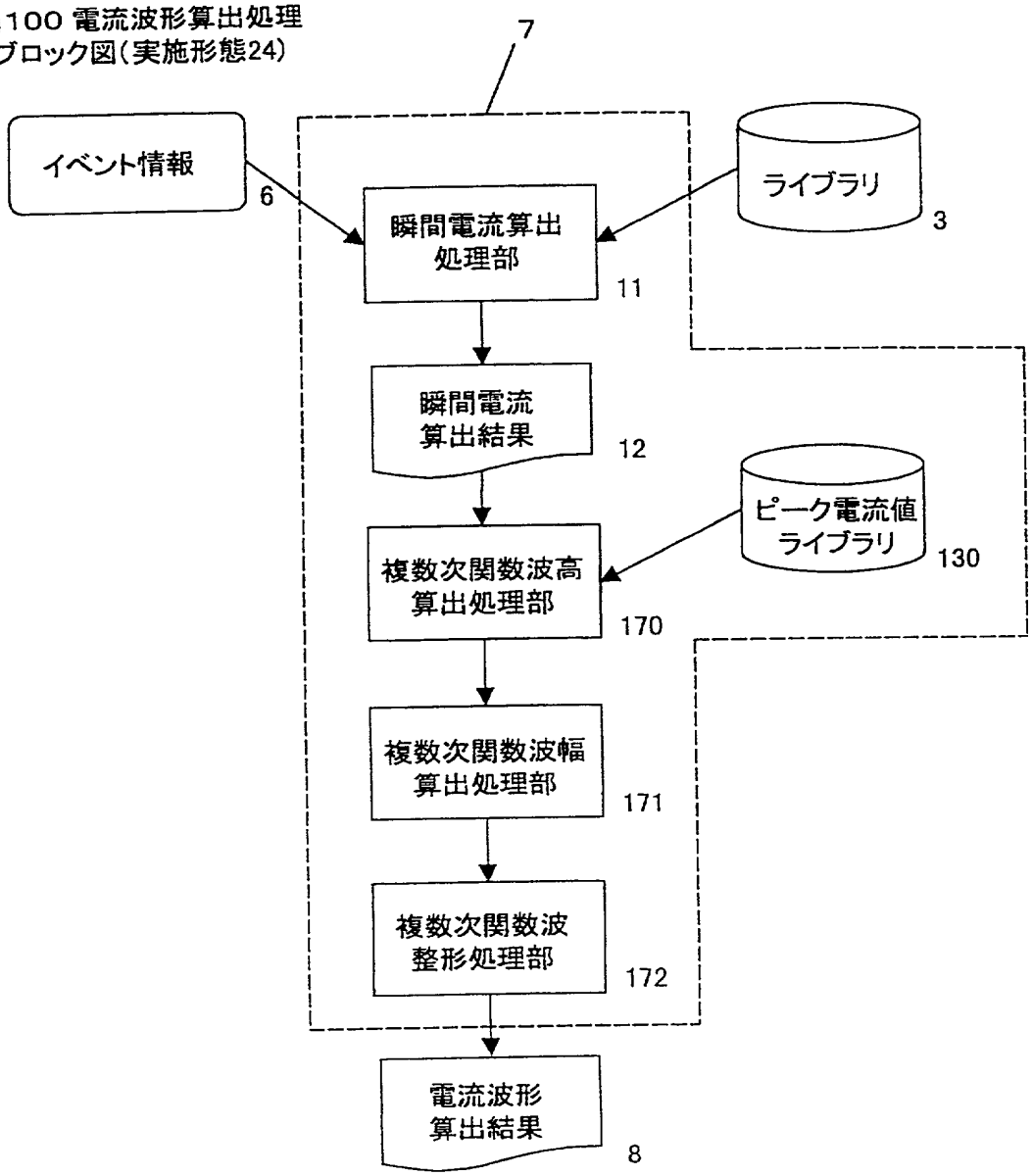
$$w = \frac{15 \times i}{16 \times h}$$

$$a = \frac{15}{16 \times w^5}\ i$$

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Fig. 100

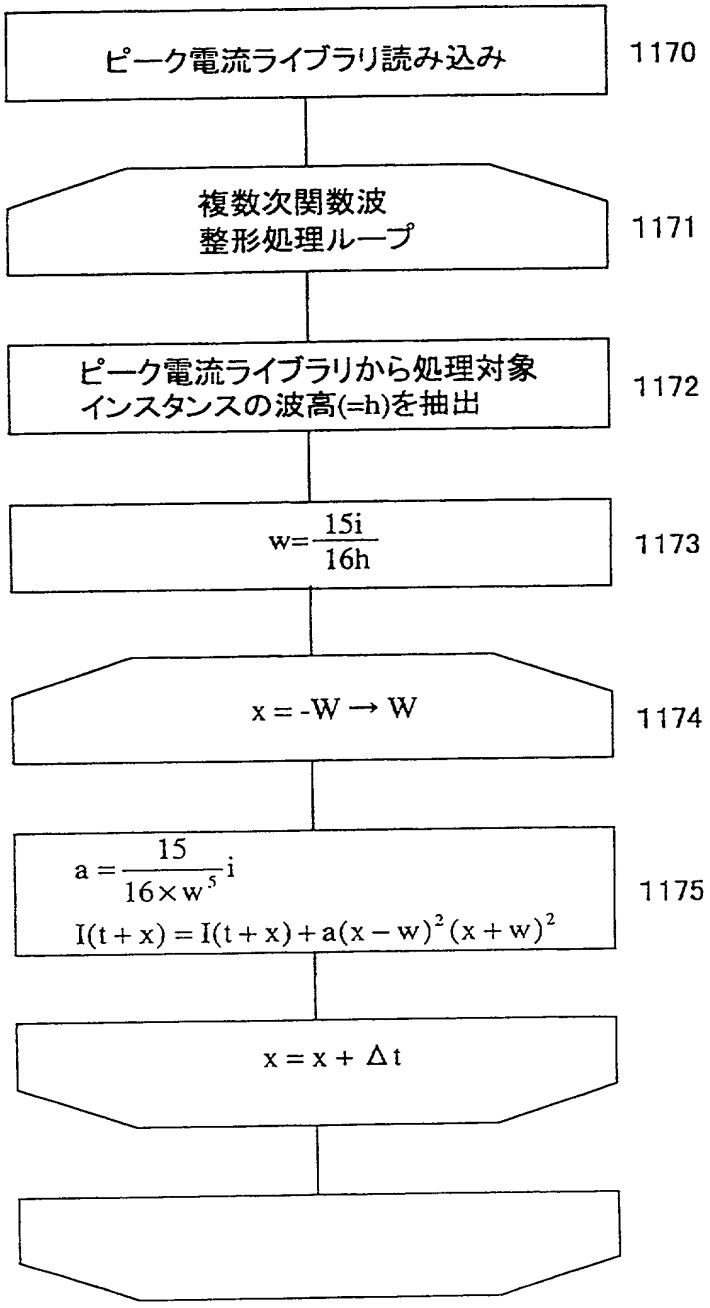
図100 電流波形算出処理
ブロック図(実施形態24)



0505258-070700

Fig.101

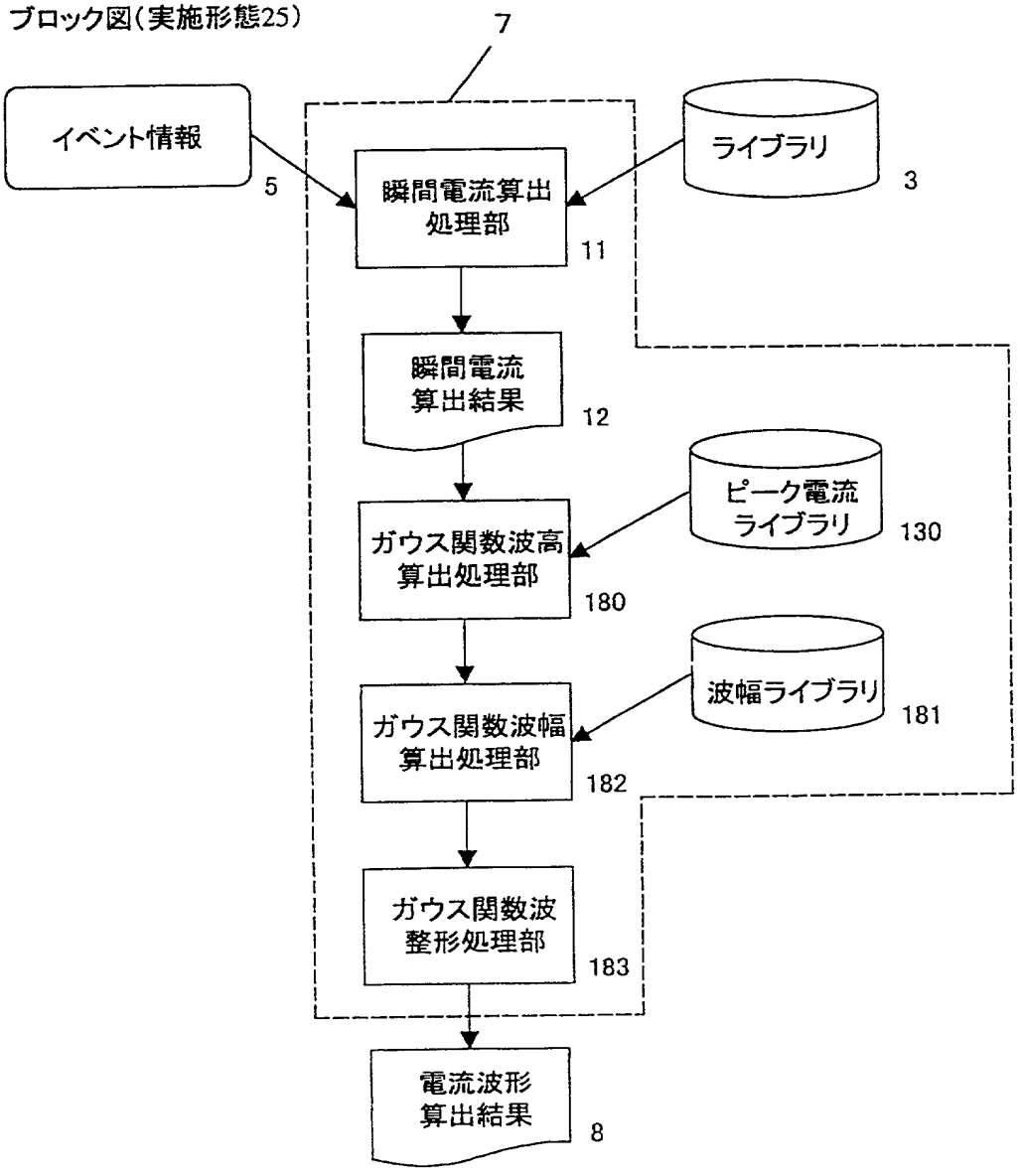
図101 複数次関数整形処理フロー図



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Fig. 102

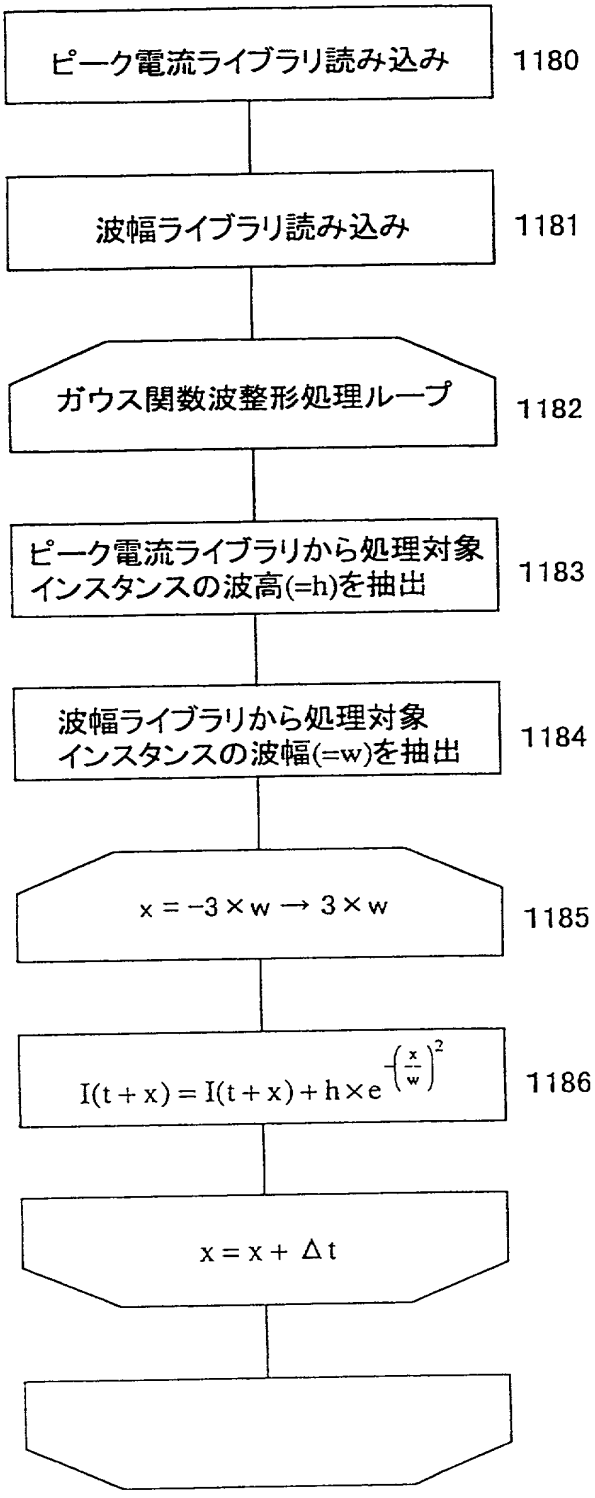
図102 電流波形算出処理
ブロック図(実施形態25)



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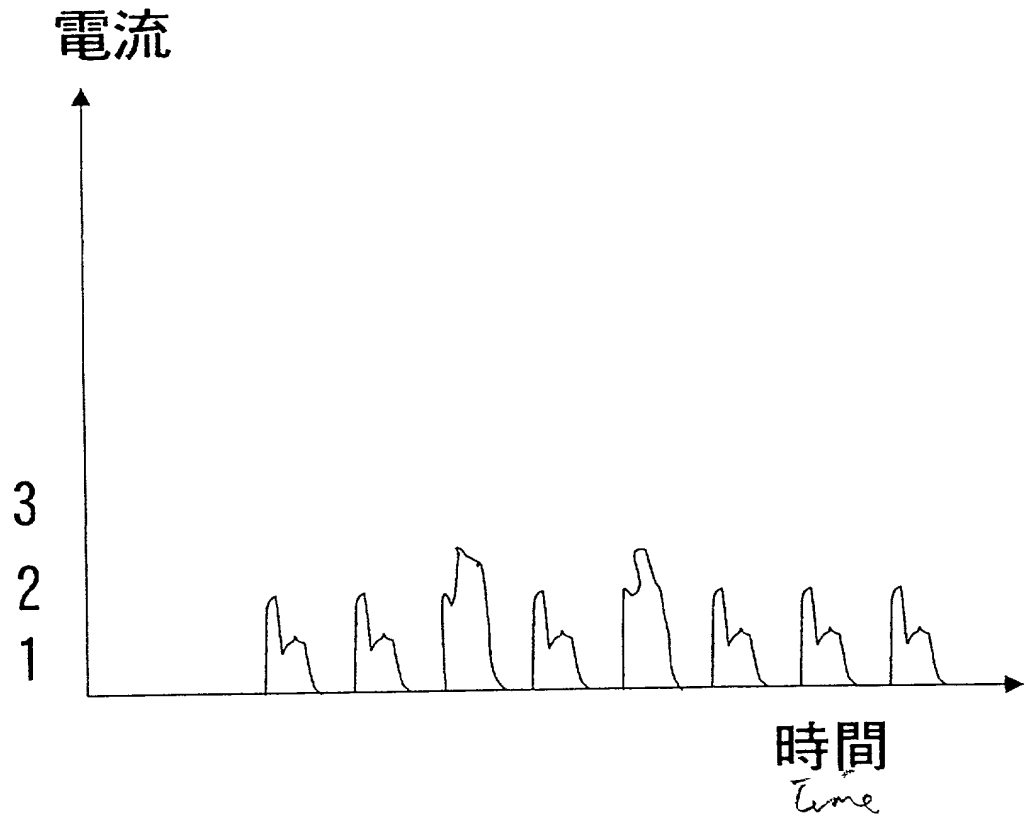
Fig. 103

図103 ガウス関数波整形処理フロー図



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Fig. 104



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Fig.105

フリップフロップFF/Q

貫通電流総量 total 3mA

貫通電流ピーク値 peak 1mA

チャージ電流総量 total 4mA

チャージ電流ピーク値 peak 2mA

フリップフロップFF/CK

貫通電流総量 total 2mA

貫通電流ピーク値 peak 1mA

チャージ電流総量 total 0mA

チャージ電流ピーク値 peak 0mA

バッファBUF/Y

貫通電流総量 total 2mA

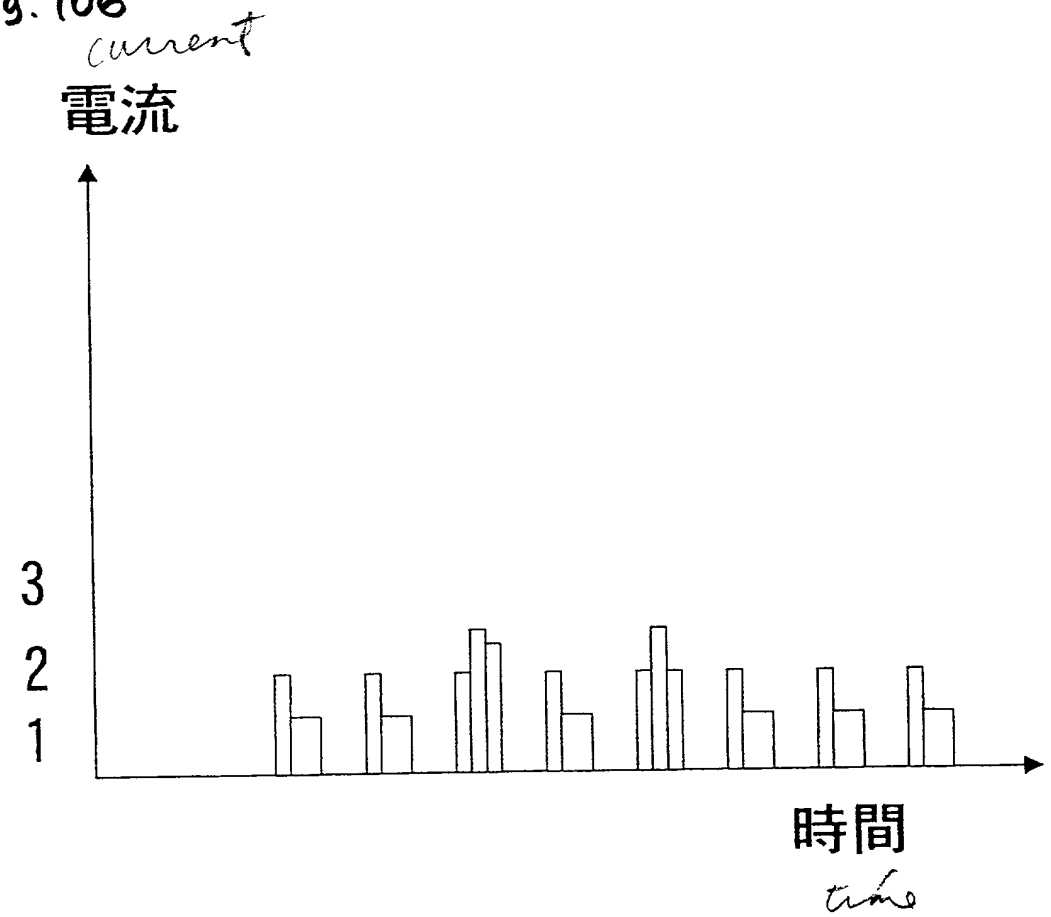
貫通電流ピーク値 peak 1mA

チャージ電流総量 total 0mA

チャージ電流ピーク値 peak 0mA

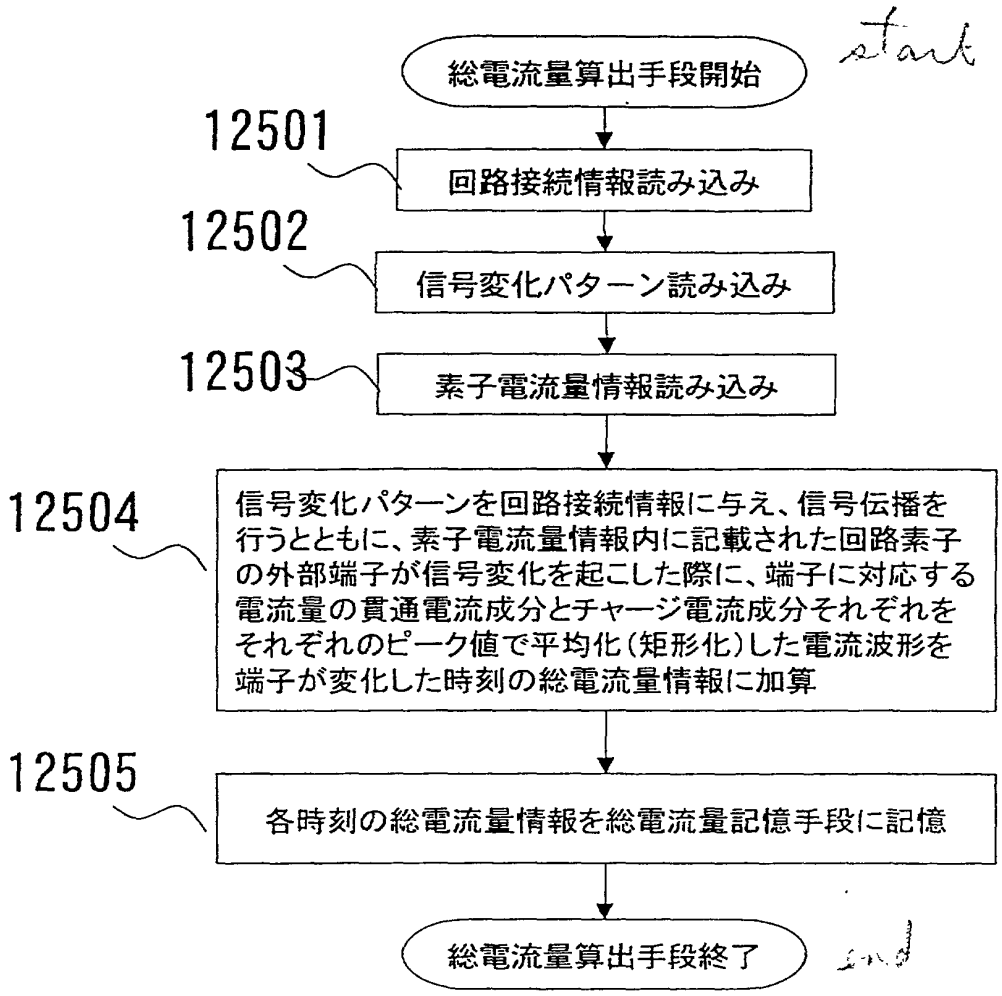
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Fig. 106



DERWENT-ACC-NO:

Fig.107



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Fig. 108

NANDNOR

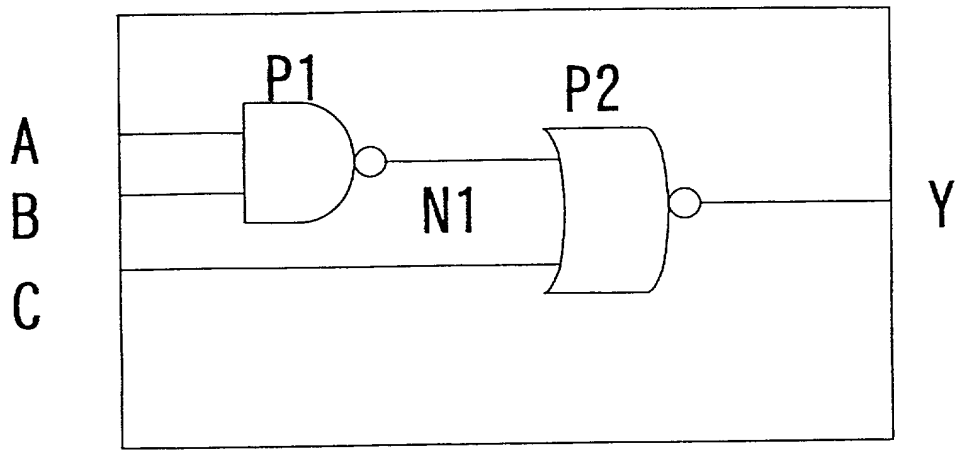


Fig. 109

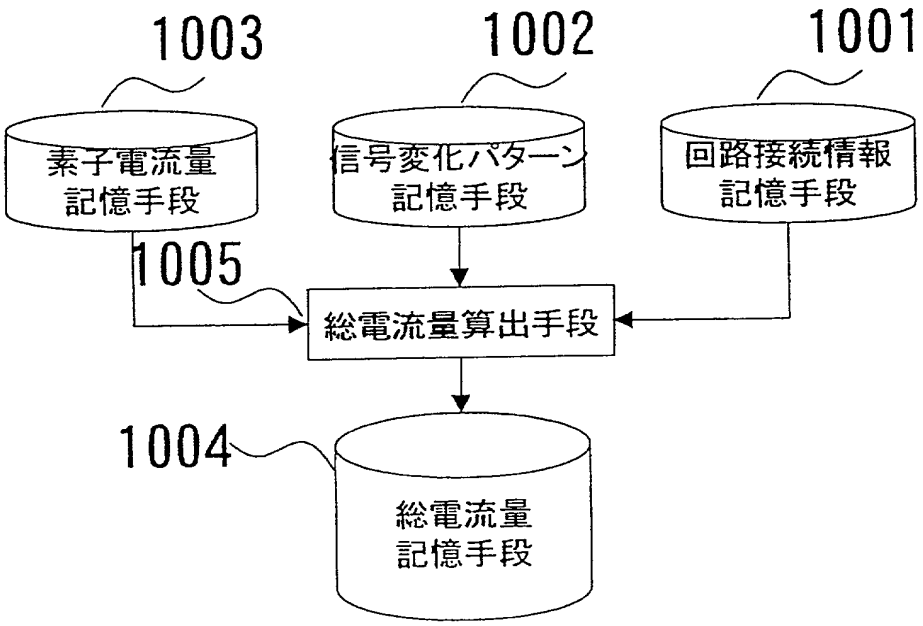


Fig. 110

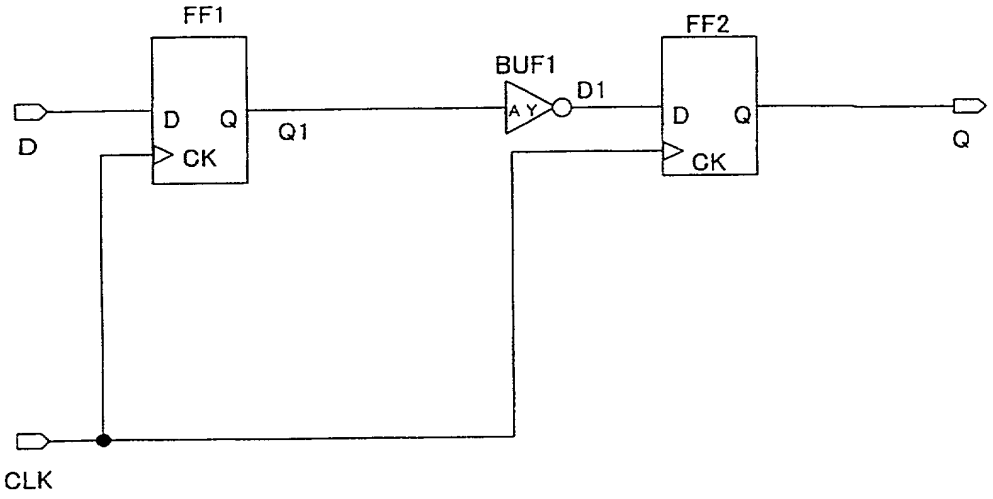


Fig. 111

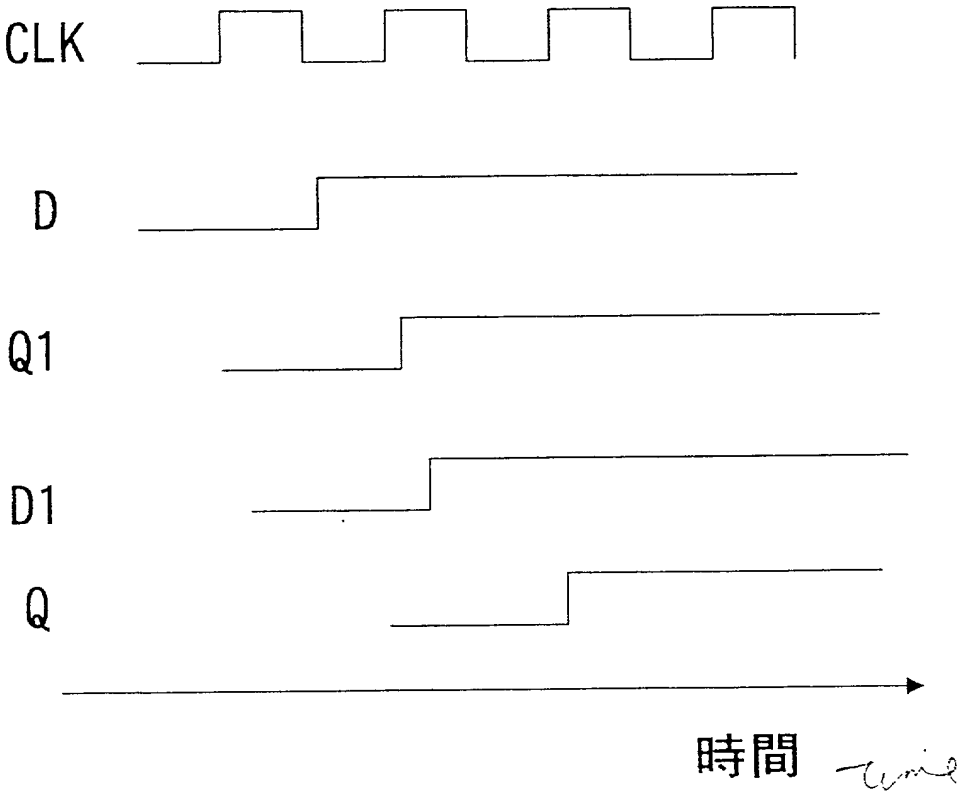
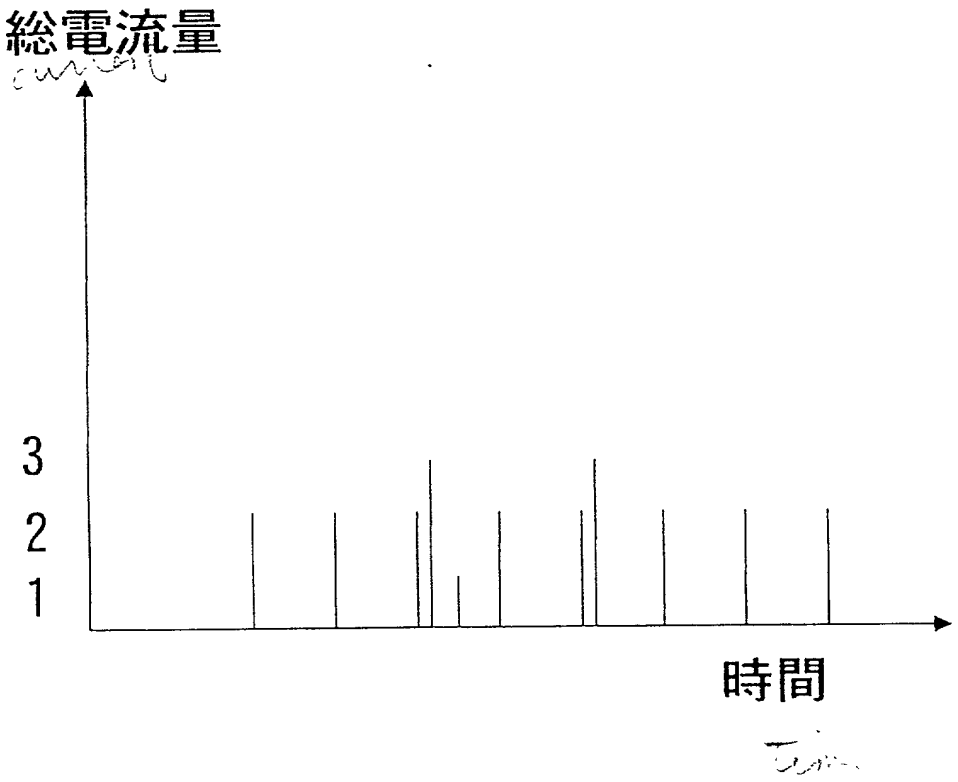


Fig.112

フリップフロップFF
Y変化時電流量　5mA　～1301
CK変化時電流量　2mA　～1302

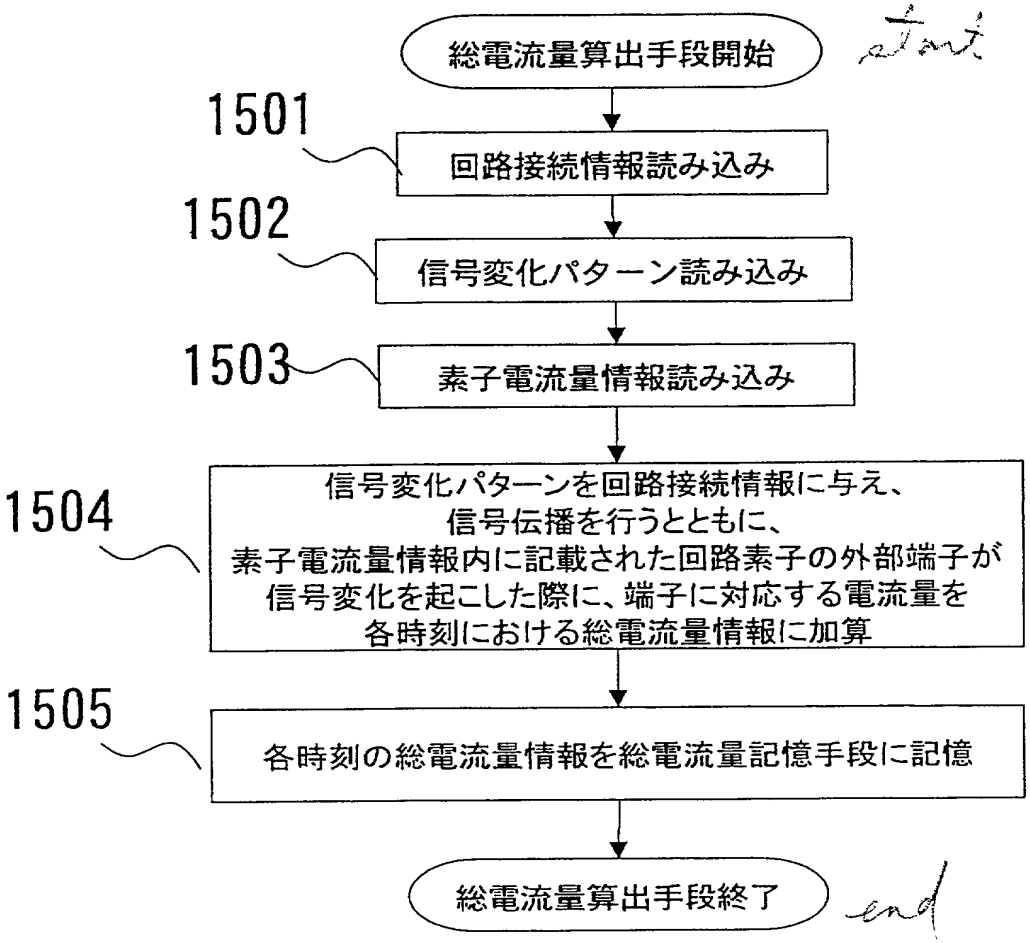
バッファBUF
Y変化時電流量　1mA　～1303

Fig.113



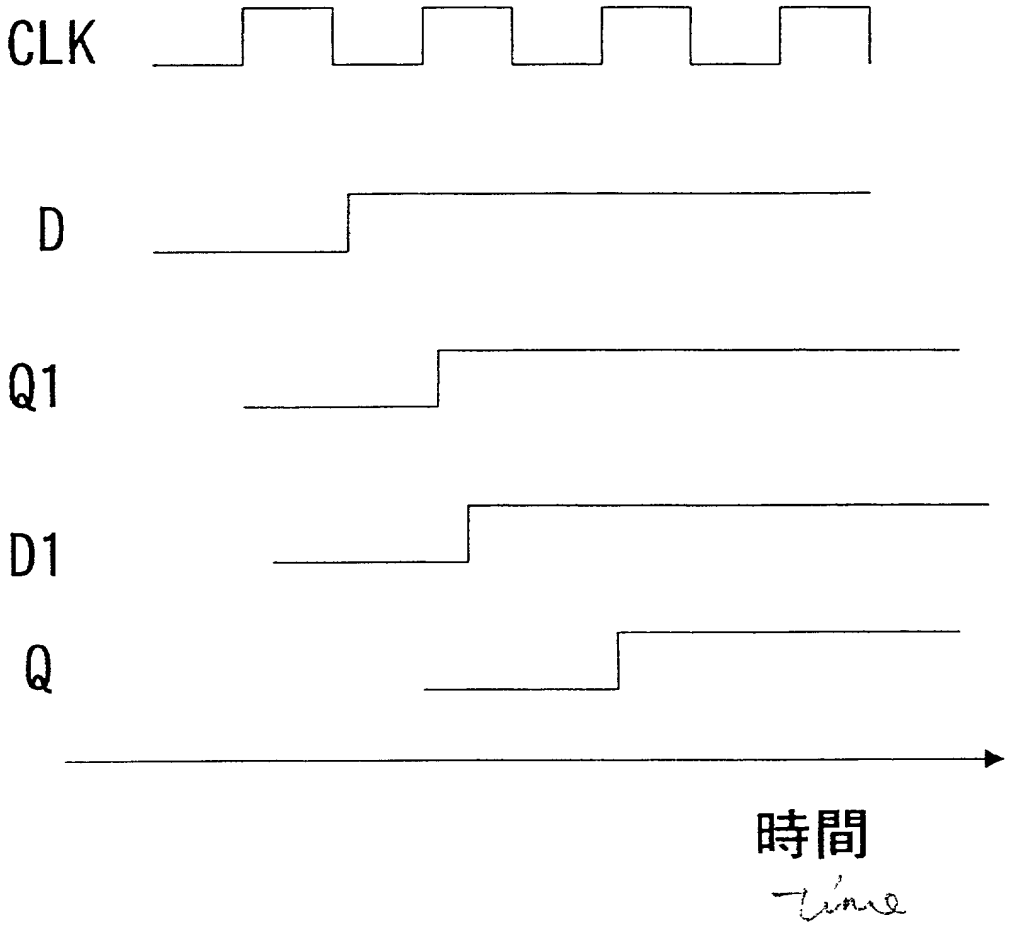
05037610033-040900

Fig. 114



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Fig. 115



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Fig.116

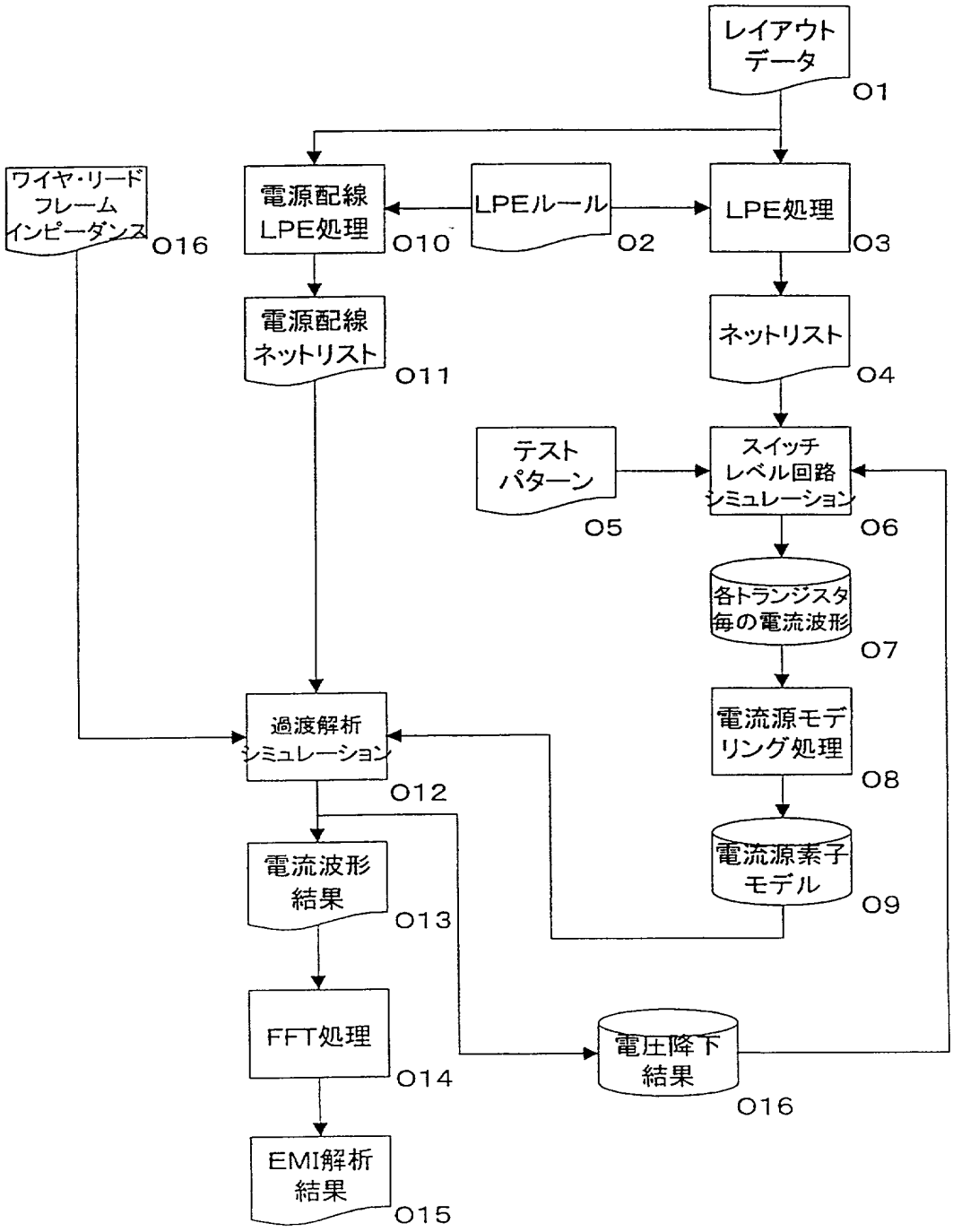
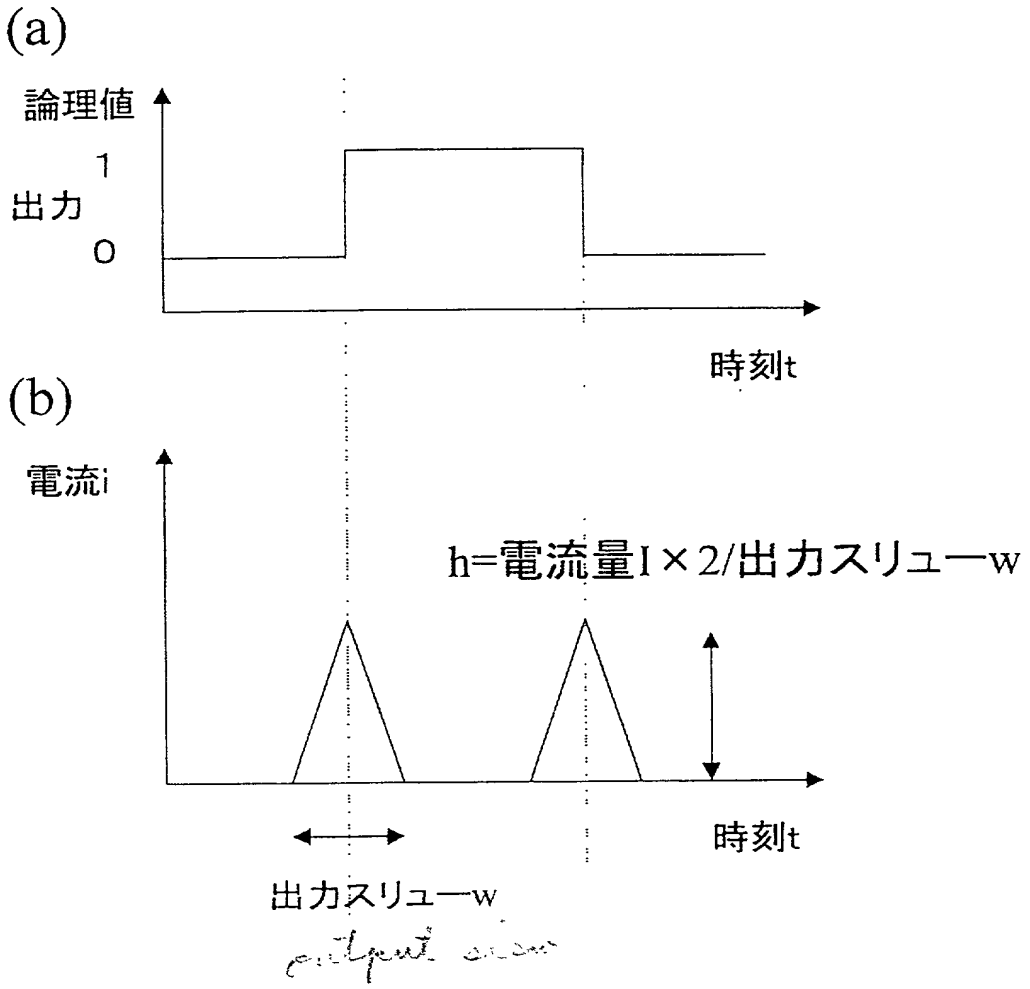
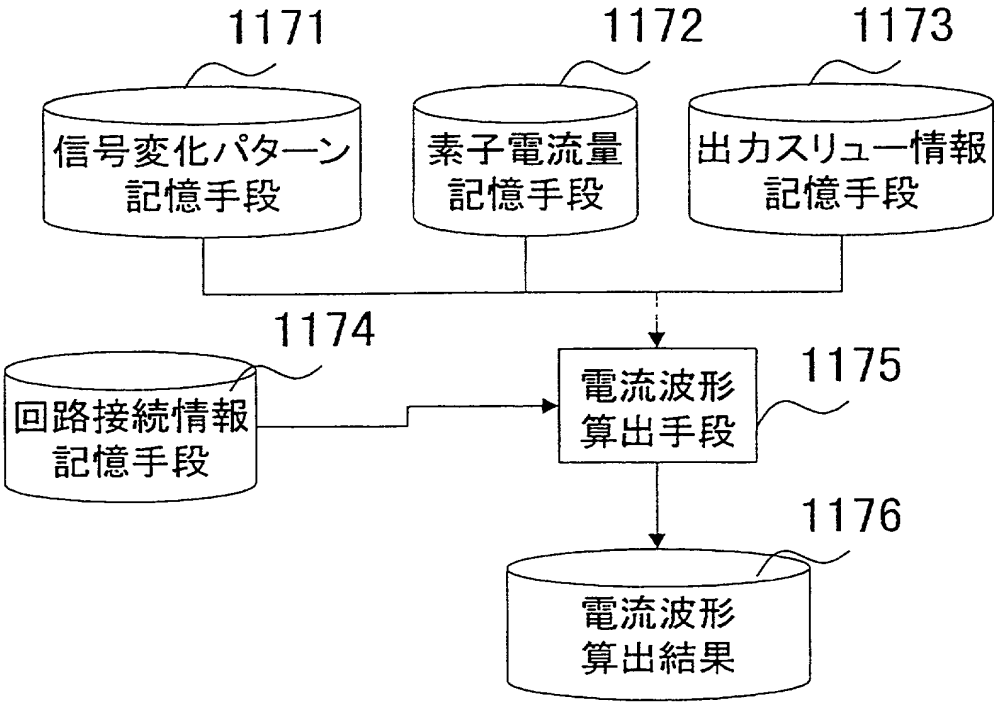

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LPE処理
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O11
ネットリスト
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テストパターン
O5
スイッチレベル回路シミュレーション
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Fig.117



DOCKET.COM

Fig. 118



DOCKET NO: 0053-0100

Fig. 119

電流波形算出手段処理フロー図

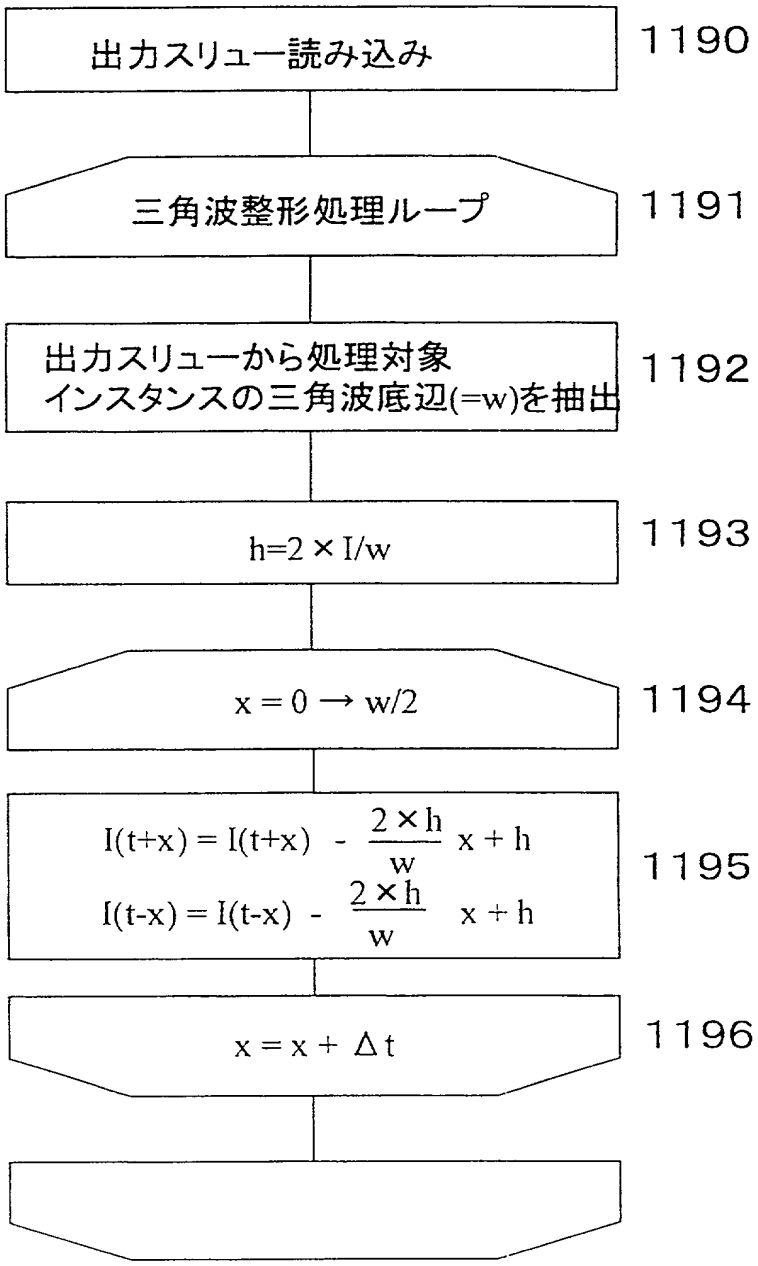
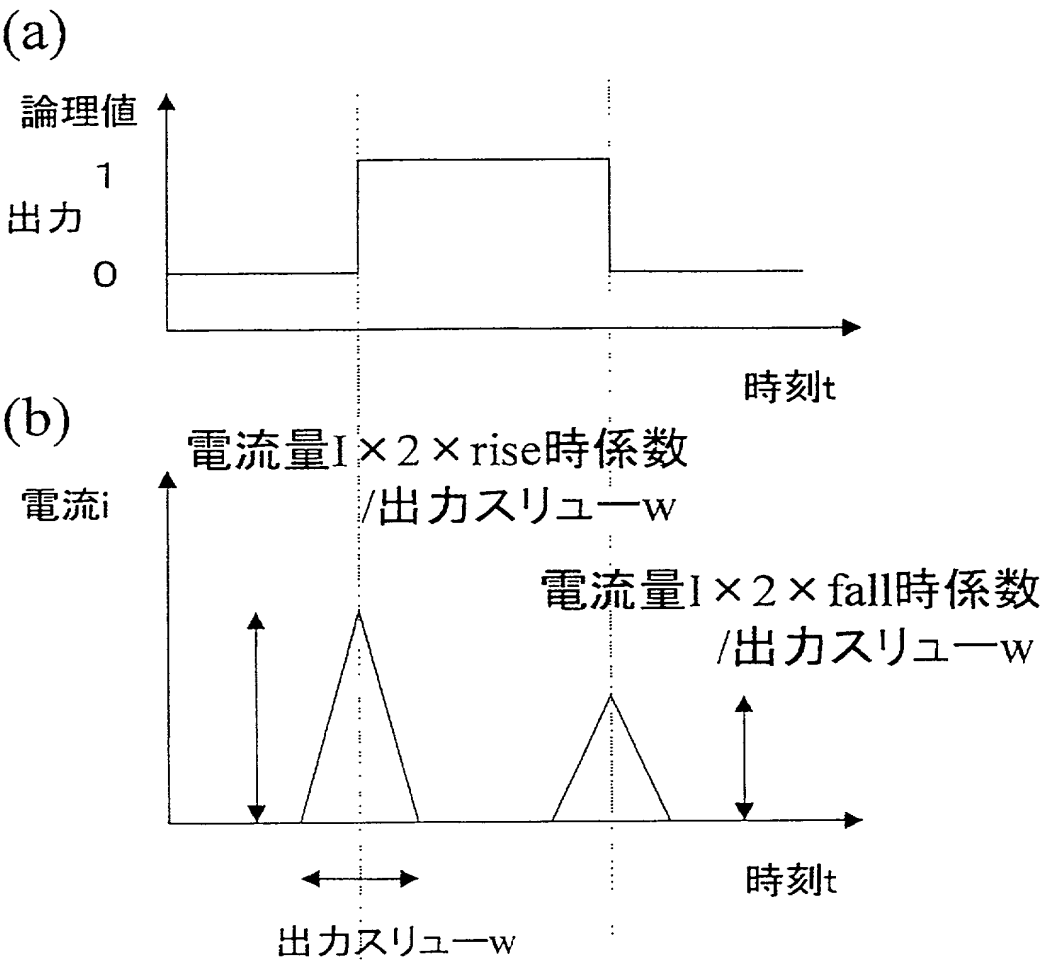


Fig.120



※fall時係数=2-rise時係数

0505P05852-US-000

Fig.121

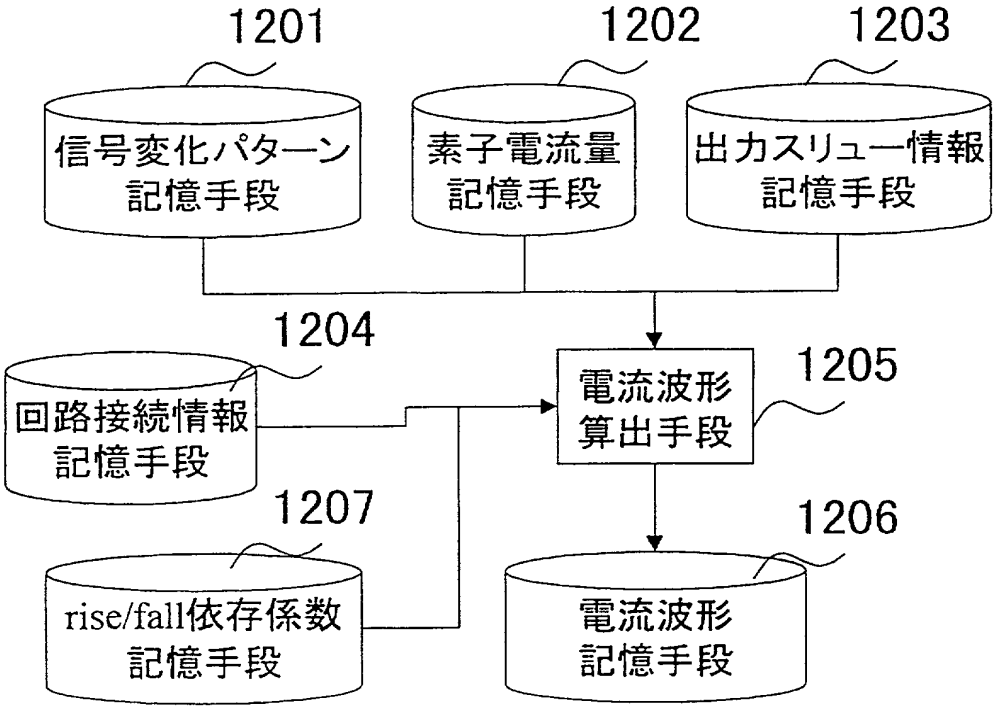
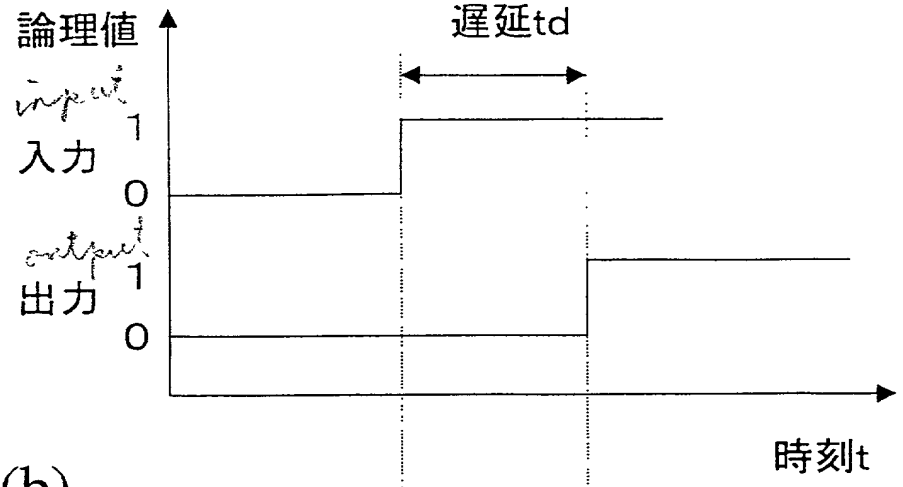
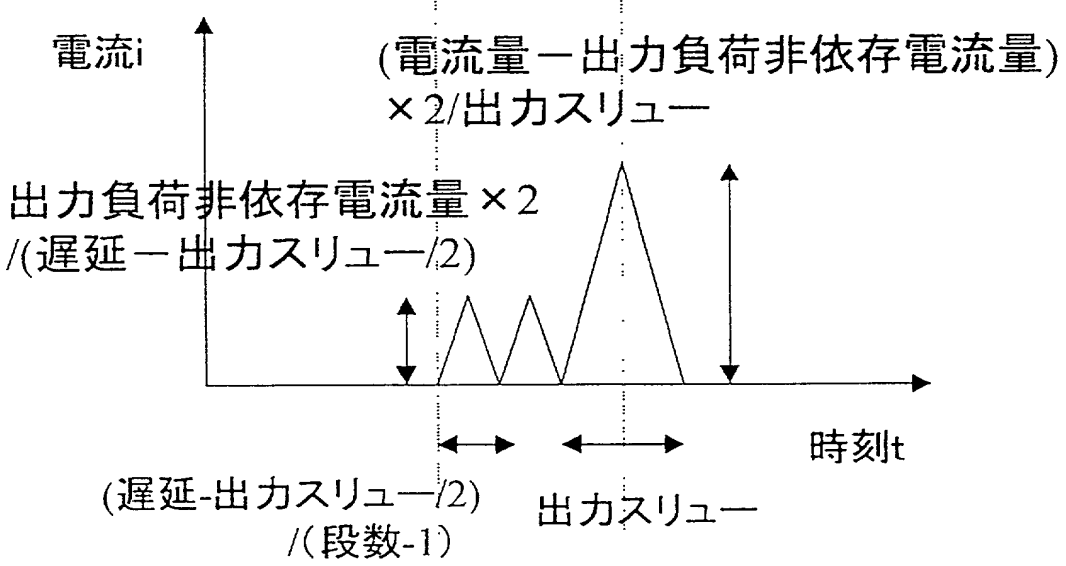

1201
1202
1203
信号変化パターン記憶手段
素子電流量記憶手段
出力スリュー情報記憶手段
1204
回路接続情報記憶手段
電流波形算出手段
1205
1207
rise/fall依存係数記憶手段
1206
電流波形記憶手段

Fig. 122

(a)

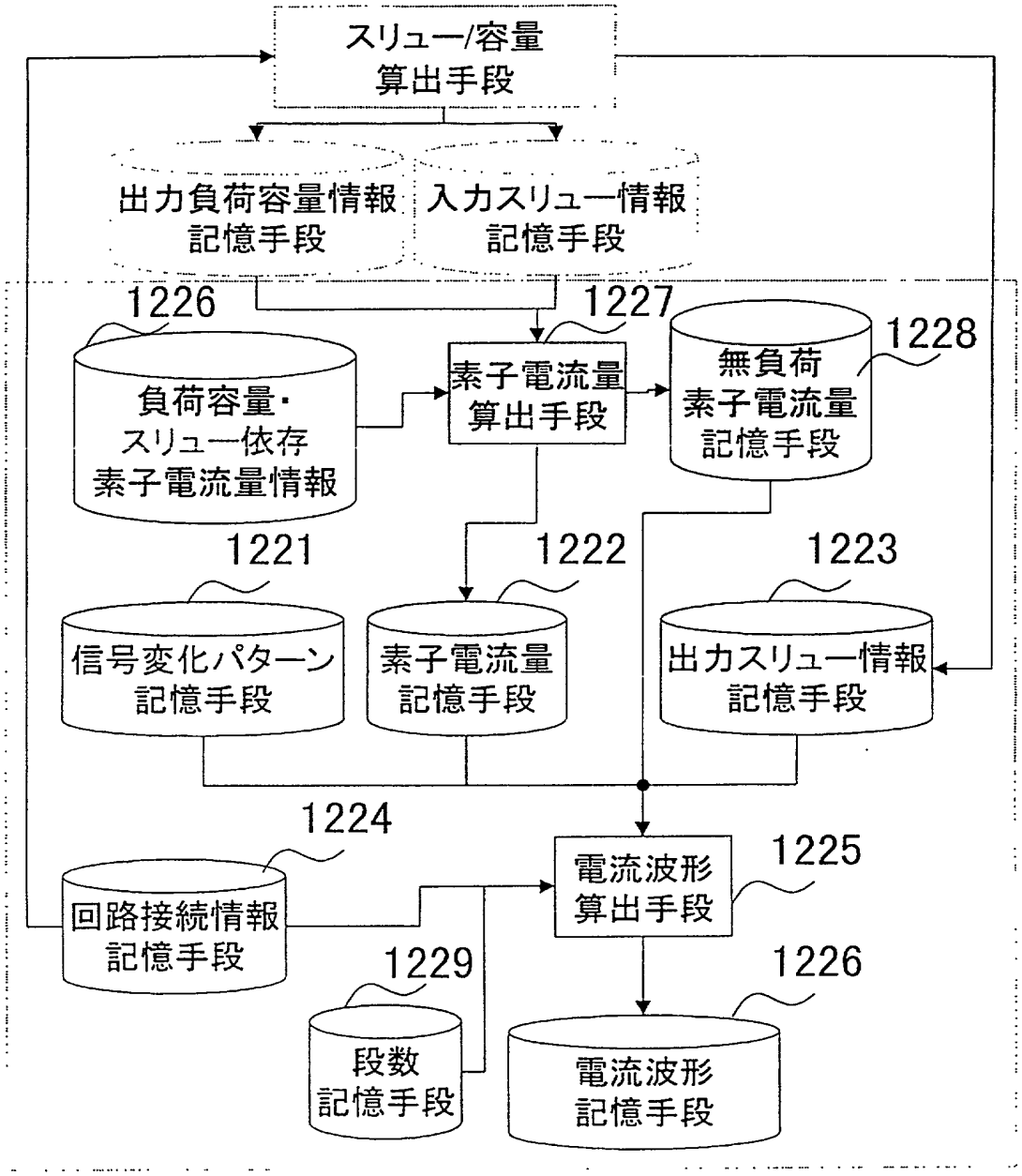


(b)



0056205.0200

Fig. 123



0951258-070700

[Description of Reference Numerals]

1 net list

2 test vector

3 library

4 logic simulator

5 event information

6 simulation result

7 current waveform calculation section

8 current waveform calculation result

9 FFT processing section

10 result of EMI analysis

11 instantaneously-changing current calculation section

12 calculation result of instantaneously-changing current

13 current waveform averaging section

20 first rectangular waveform height calculation section

21 first rectangular waveform-shaping section

30 second rectangular waveform height calculation section

31 second rectangular waveform width calculation section

32 second rectangular waveform-shaping section

40 i-h table

41 third rectangular waveform height calculation section

42 third rectangular waveform width calculation section

43 third rectangular waveform-shaping section

50 i-s-h table

51 Slew data

52 fourth rectangular waveform height calculation section

53 fourth rectangular waveform width calculation section

54 fourth rectangular waveform-shaping section

60 i-c-h table

61 capacitance data

62 fifth rectangular waveform height calculation section

63 fifth rectangular waveform width calculation section

64 fifth rectangular waveform-shaping section

100 triangular waveform height calculation section

101 triangular waveform-shaping section

120 Gaussian function waveform height calculation section

121 i-w table

122 Gaussian function waveform width calculation section

123 Gaussian function waveform-shaping section

130 peak current library

131 sixth rectangular waveform height calculation section

132 sixth rectangular waveform width calculation section

133 sixth rectangular waveform shaping section

140 s-h table

141 seventh rectangular waveform height calculation section

142 seventh rectangular waveform width calculation section

143 seventh rectangular waveform shaping section

150 c-h table

151 eighth rectangular waveform height calculation section

152 eighth rectangular waveform width calculation section

153 eighth rectangular waveform shaping section

160 triangular waveform height calculation section

161 triangular waveform width calculation section

162 triangular waveform shaping section

170 multi-order-function waveform height calculation section

171 multi-order-function waveform width calculation section

172 multi-order-function waveform shaping section

180 Gaussian function waveform height calculation section

181 width library

182 Gaussian function waveform width calculation section

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183 Gaussian function waveform shaping section

0961258 0707700

[DESIGNATION OF DOCUMENT] ABSTRACT OF THE DISCLOSURE

[ABSTRACT]

[PROBLEM] EMI analysis involving a transistor-scale simulation requires consumption of much processing time, and analysis of overall EMI arising in an LSI has been unrealistic. Further, a gate-scale logic simulation cannot correctly replicate a change in electric current. Hence, the gate-scale logic simulation cannot be used for EMI analysis.

[Means of Solution] In a gate-scale logic simulation, a change in electric current is calculated from event information 5 output from a logic simulator 4 through use of a current waveform calculation section 7. The thus-calculated change in current is subjected to FFT processing through use of an FFT processing section 9, thereby determining a frequency characteristic of EMI and enabling EMI analysis.

[Selected Drawing] FIG. 18

JP2003-256508-A

[DESIGNATION OF DOCUMENT]

[FIG. 1]

BLOCK DIAGRAM SHOWING OVERALL FLOW OF PROCESSING OF EMI ANALYSIS METHOD ACCORDING TO THE PRESENT INVENTION

1 NET LIST

2 TEST VECTOR

3 LIBRARY

4 LOGIC SIMULATOR

5 EVENT INFORMATION

6 SIMULATION RESULT

7 CURRENT WAVEFORM CALCULATION SECTION

8 RESULT OF CURRENT WAVEFORM CALCULATION

9 FFT PROCESSING SECTION

10 RESULT OF EMI ANALYSIS

[FIG. 2]

BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (FIRST EMBODIMENT)

3 LIBRARY

5 EVENT INFORMATION

8 CALCULATION RESULT OF CURRENT WAVEFORM

11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION

12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT

13 CURRENT WAVEFORM AVERAGING SECTION

[FIG. 3]

CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING ELECTRIC CURRENT

AMOUNT OF CURRENT

[FIG. 4]

FLOWCHART FOR AVERAGING CURRENT WAVEFORM

STEP S1010 AVERAGING LOOP

[FIG. 5]

CALCULATION RESULT OF CURRENT WAVEFORM (FIRST EMBODIMENT)

09612582 "070700

AT T=5

[FIG. 6]
RESULT OF FFT ANALYSIS
INTENSITY
FREQUENCY

[FIG. 7]
RECTANGULAR WAVEFORM MODEL (SECOND EMBODIMENT)
W IS CONSTANT

[FIG. 8]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (SECOND EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
20 FIRST RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
21 FIRST RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 9]
FLOWCHART OF FIRST RECTANGULAR WAVEFORM SHAPING OPERATION
1020 RECTANGULAR WAVEFORM SHAPING LOOP

[FIG. 10]
CALCULATION RESULT OF CURRENT WAVEFORM (SECOND EMBODIMENT)
AT W = 5

[FIG. 11]
RECTANGULAR WAVEFORM MODEL (THIRD EMBODIMENT)
h/w = K = CONSTANT

[FIG. 12]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION

(THIRD EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
30 SECOND RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
31 SECOND RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
32 SECOND RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 13]
FLOWCHART OF SECOND RECTANGULAR WAVEFORM SHAPING OPERATION
1030 RECTANGULAR WAVEFORM SHAPING LOOP

[FIG. 14]
CALCULATION RESULT OF CURRENT WAVEFORM (THIRD EMBODIMENT) AT K=4

[FIG. 15]
RECTANGULAR WAVEFORM MODEL (FOURTH, FIFTH, AND SIXTH EMBODIMENTS)

[FIG. 16]
i-h TABLE
IN THE CASE OF i=70

[FIG. 17]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (FOURTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
40 i-h TABLE
41 THIRD RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION

42 THIRD RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
43 THIRD RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 18]
FLOWCHART OF THIRD RECTANGULAR WAVEFORM SHAPING OPERATION
1040 READ i-h TABLE
1041 RECTANGULAR WAVEFORM SHAPING LOOP
1042 EXTRACT (i1, h1) (i2, h2)

[FIG. 19]
CALCULATION RESULT OF CURRENT WAVEFORM (FOURTH EMBODIMENT)

[FIG. 20]
i-s-h TABLE
IN THE CASE OF i=70, s=1

[FIG. 21]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION
(FIFTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
50 i-s-h TABLE
51 SLEW DATA
52 FOURTH RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
53 FOURTH RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
54 FOURTH RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 22]
FLOWCHART OF FOURTH RECTANGULAR WAVEFORM SHAPING OPERATION
1050 READ i-s-h TABLE
1051 READ SLEW DATA
1052 RECTANGULAR WAVEFORM SHAPING LOOP
1053 EXTRACT (s1, i1), (s1, i2), (s2, i1), (s2, i2)

[FIG. 23]
CALCULATION RESULT OF CURRENT WAVEFORM (FIFTH EMBODIMENT) IN THE CASE OF i=70, C=10

[FIG. 24]
i-c-h TABLE

[FIG. 25]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (SIXTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
60 i-c-h TABLE
61 CAPACITANCE DATA
62 FIFTH RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
63 FIFTH RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
64 FIFTH RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 26]
FLOWCHART OF FIFTH RECTANGULAR WAVEFORM SHAPING OPERATION
1060 READ i-c-h TABLE
1061 READ CAPACITANCE DATA
1062 RECTANGULAR WAVEFORM SHAPING LOOP
1063 EXTRACT

[FIG. 27]
CALCULATION RESULT OF CURRENT WAVEFORM (SIXTH EMBODIMENT)

[FIG. 28]
1 NET LIST
2 TEST VECTOR
3 LIBRARY

4 LOGIC SIMULATOR
5 EVENT INFORMATION
6 SIMULATION RESULT
8 CALCULATION RESULT OF CURRENT WAVEFORM
9 FFT PROCESSING SECTION
10 RESULT OF EMI ANALYSIS
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
13 CURRENT WAVEFORM AVERAGING SECTION
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE
A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION
A11 LINE VOLTAGE DROP CALCULATION/INSTANTANEOUSLY-CHANGING CURRENT CORRECTION SECTION

[FIG. 29]
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE
A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION
B1 INFORMATION CONCERNING INSTANTANEOUSLY-CHANGING CURRENT FOR EACH INSTANCE
B2 EXTRACTION OF POWER NET
B3 CALCULATION OF CURRENT FLOWING IN EACH SEGMENT
B4 INFORMATION CONCERNING EACH SEGMENT IN POWER LINE
B5 INFORMATION CONCERNING CURRENT PER EACH SEGMENT
B6 CALCULATION OF RESISTANCE OF EACH SEGMENT
B7 CALCULATION OF VOLTAGE DROP IN EACH SEGMENT
B8 INFORMATION CONCERNING RESISTANCE OF EACH SEGMENT
B9 INFORMATION CONCERNING VOLTAGE DROP IN EACH SEGMENT
B10 CALCULATION OF VOLTAGE DROP OF EACH INSTANCE
B11 INFORMATION CONCERNING VOLTAGE DROP IN EACH INSTANCE
B12 CORRECTION OF ELECTRIC CURRENT

[FIG. 30]
INSTANCE 1, INSTANCE 2, INSTANCE 3

[FIG. 31]
INSTANCE 1, INSTANCE 2, INSTANCE 3

[FIG. 32]
INSTANCE 1, INSTANCE 2, INSTANCE 3

[FIG. 33]
INSTANCE 1, INSTANCE 2, INSTANCE 3

[FIG. 34]
INSTANCE 1, INSTANCE 2, INSTANCE 3

[FIG. 35]
INSTANCE 1, INSTANCE 2, INSTANCE 3
VOLTAGE DROP IN INSTANCE 1
VOLTAGE DROP IN INSTANCE 2
VOLTAGE DROP IN INSTANCE 3

[FIG. 36]
1 NET LIST
2 TEST VECTOR
3 LIBRARY
4 LOGIC SIMULATOR
5 EVENT INFORMATION
6 SIMULATION RESULT
8 CALCULATION RESULT OF CURRENT WAVEFORM
9 FFT PROCESSING SECTION
10 RESULT OF EMI ANALYSIS
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
13 CURRENT WAVEFORM AVERAGING SECTION
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE

A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION
C1 C-V TABLE OR C-V FUNCTION
C2 LINE VOLTAGE DROP CALCULATION/INSTANTANEOUSLY-CHANGING CURRENT CORRECTION SECTION

[FIG. 37]
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE
A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION
C1 C-V TABLE OR C-V FUNCTION
B1 INFORMATION CONCERNING INSTANTANEOUSLY-CHANGING CURRENT FOR EACH INSTANCE
B2 EXTRACTION OF POWER NET
B3 CALCULATION OF CURRENT FLOWING IN EACH SEGMENT
B4 INFORMATION CONCERNING EACH SEGMENT IN POWER LINE
B5 INFORMATION CONCERNING CURRENT PER EACH SEGMENT
B6 CALCULATION OF RESISTANCE OF EACH SEGMENT
B8 INFORMATION CONCERNING RESISTANCE OF EACH SEGMENT
B9 INFORMATION CONCERNING VOLTAGE DROP IN EACH SEGMENT
B10 CALCULATION OF VOLTAGE DROP OF EACH INSTANCE
B11 INFORMATION CONCERNING VOLTAGE DROP IN EACH INSTANCE
B12 CORRECTION OF ELECTRIC CURRENT
D1 CALCULATION OF CAPACITANCE PROVIDED BETWEEN SEGMENTS
D2 INFORMATION CONCERNING CAPACITANCE PROVIDED BETWEEN SEGMENTS
D3 CALCULATION OF VOLTAGE DROP IN EACH SEGMENT

[FIG. 38]
INSTANCE 1, INSTANCE 2, INSTANCE 3

[FIG. 39]
INSTANCE 1, INSTANCE 2, INSTANCE 3
VOLTAGE DROP IN INSTANCE 1

VOLTAGE DROP IN INSTANCE 2
VOLTAGE DROP IN INSTANCE 3

[FIG. 40]
1 NET LIST
2 TEST VECTOR
3 LIBRARY
4 LOGIC SIMULATOR
5 EVENT INFORMATION
6 SIMULATION RESULT
8 CALCULATION RESULT OF CURRENT WAVEFORM
9 FFT PROCESSING SECTION
10 RESULT OF EMI ANALYSIS
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
13 CURRENT WAVEFORM AVERAGING SECTION
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE
A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION
E1 LINE VOLTAGE DROP CALCULATION/INSTANTANEOUSLY-CHANGING CURRENT CORRECTION SECTION

[FIG. 41]
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE
A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION
B1 INFORMATION CONCERNING INSTANTANEOUSLY-CHANGING CURRENT FOR EACH INSTANCE
B2 EXTRACTION OF POWER NET
B4 INFORMATION CONCERNING EACH SEGMENT IN POWER LINE
B6 CALCULATION OF RESISTANCE OF EACH SEGMENT
B8 INFORMATION CONCERNING RESISTANCE OF EACH SEGMENT
B11 INFORMATION CONCERNING VOLTAGE DROP IN EACH INSTANCE

B12 CORRECTION OF ELECTRIC CURRENT
D1 CALCULATION OF CAPACITANCE PROVIDED BETWEEN SEGMENTS
D2 INFORMATION CONCERNING CAPACITANCE PROVIDED BETWEEN SEGMENTS
F1 TRANSIENT ANALYSIS

[FIG. 42]
TRIANGULAR WAVEFORM MODEL (TENTH EMBODIMENT)
W IS CONSTANT

[FIG. 43]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (TENTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
100 TRIANGULAR WAVEFORM HEIGHT CALCULATION SECTION
101 TRIANGULAR WAVEFORM SHAPING SECTION

[FIG. 44]
FLOWCHART OF FIFTH TRIANGULAR WAVEFORM SHAPING OPERATION
1100 TRIANGULAR WAVEFORM SHAPING LOOP

[FIG. 45]
CALCULATION RESULT OF CURRENT WAVEFORM (TENTH EMBODIMENT) AT W=5

[FIG. 46]
MULTI-ORDER-FUNCTION MODEL (ELEVENTH EMBODIMENT)
W IS CONSTANT
IN THE CASE OF W=2.5, i=100
IN THE CASE OF W=2.5, i=50

[FIG. 47]

BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (ELEVENTH EMBODIMENT)

3 LIBRARY

5 EVENT INFORMATION

8 CALCULATION RESULT OF CURRENT WAVEFORM

11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION

12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT

110 MULTI-ORDER-FUNCTION WAVEFORM HEIGHT CALCULATION SECTION

111 MULTI-ORDER-FUNCTION WAVEFORM SHAPING SECTION

[FIG. 48]

FLOWCHART OF MULTI-ORDER-FUNCTION WAVEFORM SHAPING OPERATION

1110 MULTI-ORDER-FUNCTION WAVEFORM SHAPING LOOP

[FIG. 49]

CALCULATION RESULT OF CURRENT WAVEFORM (ELEVENTH EMBODIMENT) AT W=2.5

[FIG. 50]

GAUSSIAN FUNCTION MODEL (TWELFTH AND TWENTY-FIFTH EMBODIMENTS)

[FIG. 51]

i-h TABLE

IN THE CASE OF i=50, 100

[FIG. 52]

i-w TABLE

IN THE CASE OF i=50, 100

[FIG. 53]

BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION (TWELFTH EMBODIMENT)

3 LIBRARY

5 EVENT INFORMATION

8 CALCULATION RESULT OF CURRENT WAVEFORM

11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION

12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
40 i-h TABLE
121 i-w TABLE
120 GAUSSIAN FUNCTION WAVEFORM HEIGHT CALCULATION SECTION
122 GAUSSIAN FUNCTION WAVEFORM WIDTH CALCULATION SECTION
123 GAUSSIAN FUNCTION WAVEFORM SHAPING SECTION

[FIG. 54]
FLOWCHART OF GAUSSIAN FUNCTION WAVEFORM SHAPING
1120 READ i-h TABLE
1121 READ i-w TABLE
1122 PERFORM GAUSSIAN FUNCTION WAVEFORM SHAPING LOOP
1123 EXTRACT
1125 EXTRACT

[FIG. 55]
CALCULATION RESULT OF CURRENT WAVEFORM (TWELFTH EMBODIMENT)

[FIG. 56]
7301 CIRCUIT CONNECTION INFORMATION STORAGE MEANS
7302 PATTERN-OF-SIGNAL-CHANGE STORAGE MEANS
7303 ELEMENT CURRENT STORAGE MEANS
7304 TOTAL CURRENT STORAGE MEANS
7605 TOTAL CURRENT CALCULATION MEANS
7306 MEANS FOR STORING BASIC INFORMATION FOR ESTIMATING ELECTRIC CURRENT

[FIG. 57]
FLIP-FLIP FF
THE AMOUNT OF SHORT CIRCUIT CURRENT FLOWING WHEN Y IS CHANGED
THE AMOUNT OF CHARGE CURRENT FLOWING WHEN Y IS CHANGED
THE AMOUNT OF SHORT CIRCUIT CURRENT FLOWING WHEN CK IS CHANGED
THE AMOUNT OF CHARGE CURRENT FLOWING WHEN CK IS CHANGED

BUFFER BUF
THE AMOUNT OF SHORT CIRCUIT CURRENT FLOWING WHEN Y IS CHANGED

THE AMOUNT OF CHARGE CURRENT FLOWING WHEN Y IS CHANGED

[FIG. 58]
CURRENT
TIME

[FIG. 59]
7601 DISCRETE WIDTH USED FOR AVERAGING SHORT CIRCUIT CURRENT COMPONENT
7602 DISCRETE WIDTH USED FOR AVERAGING CHARGE CURRENT COMPONENT

[FIG. 60]
START ACTIVATION OF TOTAL CURRENT CALCULATION MEANS
7701 READ CIRCUIT CONNECTION INFORMATION
7702 READ PATTERN OF SIGNAL CHANGE
7703 READ INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING IN ELEMENT
7704 READ BASIC INFORMATION FOR ESTIMATING ELECTRIC CURRENT
7705 IMPART A PATTER OF SIGNAL CHANGE TO CIRCUIT CONNECTION INFORMATION, TO THEREBY ENABLE PROPAGATION OF A SIGNAL. IN A CASE WHERE A CHANGE HAS ARISEN IN A SIGNAL APPEARING AT AN EXTERNAL INPUT TERMINAL OF A CIRCUIT ELEMENT, THE ELEMENT BEING DESCRIBED IN THE INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH AN ELEMENT, ADD A SHORT CIRCUIT CURRENT COMPONENT AND A CHARGE CURRENT COMPONENT INCLUDED IN THE ELECTRIC CURRENT FLOWING IN THE EXTERNAL TERMINAL, AT RESPECTIVE POINTS IN TIME, TO THE SHORT CIRCUIT CURRENT COMPONENT AND THE CHARGE CURRENT COMPONENT INCLUDED IN THE INFORMATION CONCERNING THE TOTAL AMOUNT OF ELECTRIC CURRENT, RESPECTIVELY.
7706 AVERAGE SHORT CIRCUIT CURRENT COMPONENT INCLUDED IN TOTAL CURRENT INFORMATION BY DISCRETE WIDTH THEREOF, AND AVERAGE CHARGE CURRENT COMPONENT INCLUDED IN THE SAME BY DISCRETE WIDTH THEREOF, ADD AVERAGING RESULTS TOGETHER AS TOTAL AMOUNT OF CURRENT AT RESPECTIVE TIME
7707 STORE THE TOTAL AMOUNT OF CURRENT INTO TOTAL CURRENT

STORAGE MEANS
END OF OPERATION OF TOTAL CURRENT STORAGE MEANS

[FIG. 61]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION
(FOURTEENTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
130 PEAK CURRENT LIBRARY
131 SIXTH RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
132 SIXTH RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
133 SIXTH RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 62]
FLOWCHART OF SIXTH RECTANGULAR WAVEFORM SHAPING
1130 READ PEAK CURRENT LIBRARY
1131 PERFORM RECTANGULAR WAVEFORM SHAPING LOOP
1132 EXTRACT HEIGHT OF RECTANGULAR WAVEFORM OF OBJECT INSTANCE
FROM PEAK CURRENT LIBRARY

[FIG. 63]
s-h TABLE
IN THE CASE OF s=1.2

[FIG. 64]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION
(FIFTEENTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
51 SLEW DATA

140 s-h TABLE LIBRARY
141 SEVENTH RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
142 SEVENTH RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
143 SEVENTH RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 65]
FLOWCHART OF SEVENTH RECTANGULAR WAVEFORM SHAPING
1140 READ s-h TABLE
1141 READ SLEW DATA
1142 PERFORM RECTANGULAR WAVEFORM SHAPING LOOP
1143 EXTRACT

[FIG. 66]
c-h TABLE
IN THE CASE OF c=1.2

[FIG. 67]
BLOCK DIAGRAM SHOWING A CURRENT WAVEFORM CALCULATION SECTION
(SIXTEENTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
61 CAPACITANCE DATA
150 c-h TABLE LIBRARY
151 EIGHTH RECTANGULAR WAVEFORM HEIGHT CALCULATION SECTION
152 EIGHTH RECTANGULAR WAVEFORM WIDTH CALCULATION SECTION
153 EIGHTH RECTANGULAR WAVEFORM SHAPING SECTION

[FIG. 68]
FLOWCHART OF EIGHTH RECTANGULAR WAVEFORM SHAPING
1150 READ c-h TABLE
1151 READ CAPACITANCE DATA
1152 PERFORM RECTANGULAR WAVEFORM SHAPING LOOP
1143 EXTRACT

EP 0 905 638 A2

[FIG. 69]
TIME

[FIG. 70]
CURRENT
TIME

[FIG. 71]
CURRENT
TIME

[FIG. 72]
9001 CIRCUIT CONNECTION INFORMATION STORAGE MEANS
9002 PATTERN-OF-SIGNAL-CHANGE STORAGE MEANS
9003 ELEMENT CURRENT STORAGE MEANS
9004 TOTAL CURRENT STORAGE MEANS
9005 TOTAL CURRENT CALCULATION MEANS

[FIG. 74]
CURRENT
TIME

[FIG. 75]
CHANGED PINS
TIME
TOTAL CURRENT
PEAK CURRENT

[FIG. 76]
START ACTIVATION OF TOTAL CURRENT CALCULATION MEANS
9401 READ CIRCUIT CONNECTION INFORMATION
9402 READ PATTERN OF SIGNAL CHANGE
9403 READ INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING IN ELEMENT
9404 IMPART A PATTER OF SIGNAL CHANGE TO CIRCUIT CONNECTION

INFORMATION, TO THEREBY ENABLE PROPAGATION OF A SIGNAL. IN A CASE WHERE A CHANGE HAS ARISEN IN A SIGNAL APPEARING AT AN EXTERNAL INPUT TERMINAL OF A CIRCUIT ELEMENT, THE ELEMENT BEING DESCRIBED IN THE INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH AN ELEMENT, A RECTANGULAR WAVEFORM OF ELECTRIC CURRENT IS PRODUCED, BY MEANS OF AVERAGING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH THE EXTERNAL INPUT TERMINAL BY A PEAK VALUE. THE RECTANGULAR WAVEFORM IS ADDED TO THE INFORMATION CONCERNING THE TOTAL AMOUNT OF ELECTRIC CURRENT OBTAINED AT A TIME WHICH LAGS A PREDETERMINED PERIOD OF TIME FROM THE TIME A CHANGE HAS ARISEN IN THE EXTERNAL INPUT TERMINAL 9405 STORE, INTO TOTAL CURRENT STORAGE MEANS, TOTAL AMOUNT OF CURRENT OBTAINED AT EACH TIME
END OF OPERATION OF TOTAL CURRENT STORAGE MEANS

[FIG. 78]
LOGIC VALUE
TIME

[FIG. 79]
CURRENT
TIME

[FIG. 80]
CURRENT
TIME

[FIG. 81]
EDGE
CURRENT
PEAK VALUE

[FIG. 82]
CURRENT
TIME

[FIG. 83]
START ACTIVATION OF TOTAL CURRENT CALCULATION MEANS
10101 READ CIRCUIT CONNECTION INFORMATION
10102 READ PATTERN OF SIGNAL CHANGE
10103 READ INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING IN ELEMENT
10104 IMPART A PATTER OF SIGNAL CHANGE TO CIRCUIT CONNECTION INFORMATION, TO THEREBY ENABLE PROPAGATION OF A SIGNAL. IN A CASE WHERE A CHANGE HAS ARISEN IN A SIGNAL APPEARING AT AN EXTERNAL INPUT TERMINAL OF A CIRCUIT ELEMENT, THE ELEMENT BEING DESCRIBED IN THE INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH AN ELEMENT, A RECTANGULAR WAVEFORM OF AN ELECTRIC CURRENT IS PRODUCED BY MEANS OF AVERAGING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH THE EXTERNAL INPUT TERMINAL AT A RISE AND FALL OF THE SIGNAL BY MEANS OF A PEAK VALUE. THE RECTANGULAR WAVEFORMS ARE ADDED TO THE INFORMATION CONCERNING THE TOTAL AMOUNT OF ELECTRIC CURRENT OBTAINED AT A TIME WHEN THE CHANGE HAS ARISEN IN THE SIGNAL APPEARING AT THE EXTERNAL INPUT TERMINAL.
10105 STORE, INTO TOTAL CURRENT STORAGE MEANS, TOTAL AMOUNT OF CURRENT OBTAINED AT EACH TIME
END OF OPERATION OF TOTAL CURRENT STORAGE MEANS

[FIG. 85]
TIME

[FIG. 86]
CURRENT
TIME

[FIG. 87]
CURRENT
TIME

[FIG. 88]
NOR, Y-TERMINAL

TOTAL CURRENT AT LOGIC VALUE OF 1
PEAK CURRENT AT LOGIC VALUE OF 1
TOTAL CURRENT AT LOGIC VALUE OF 0
PEAK CURRENT AT LOGIC VALUE OF 0
TOTAL CURRENT AT LOGIC VALUE OF 1
PEAK CURRENT AT LOGIC VALUE OF 1
TOTAL CURRENT AT LOGIC VALUE OF 0
PEAK CURRENT AT LOGIC VALUE OF 0
TOTAL CURRENT AT LOGIC VALUE OF 1
PEAK CURRENT AT LOGIC VALUE OF 1
TOTAL CURRENT AT LOGIC VALUE OF 0
PEAK CURRENT AT LOGIC VALUE OF 0

[FIG. 89]
START ACTIVATION OF TOTAL CURRENT CALCULATION MEANS
10701 READ CIRCUIT CONNECTION INFORMATION
10702 READ PATTERN OF SIGNAL CHANGE
10703 READ INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING IN ELEMENT
10704 IMPART A PATTER OF SIGNAL CHANGE TO CIRCUIT CONNECTION INFORMATION, TO THEREBY ENABLE PROPAGATION OF A SIGNAL. IN A CASE WHERE A CHANGE HAS ARISEN IN A SIGNAL APPEARING AT AN EXTERNAL INPUT TERMINAL OF A CIRCUIT ELEMENT, THE ELEMENT BEING DESCRIBED IN THE INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH AN ELEMENT, A RECTANGULAR WAVEFORM OF AN ELECTRIC CURRENT IS PRODUCED BY MEANS OF AVERAGING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH THE EXTERNAL INPUT TERMINAL BY MEANS OF A PEAK VALUE IN ACCORDANCE WITH THE STATUS OF ANOTHER TERMINAL. THE RECTANGULAR WAVEFORM IS ADDED TO THE INFORMATION CONCERNING THE TOTAL AMOUNT OF ELECTRIC CURRENT OBTAINED AT A TIME WHEN THE CHANGE HAS ARISEN IN THE SIGNAL APPEARING AT THE EXTERNAL INPUT TERMINAL.
10705 STORE, INTO TOTAL CURRENT STORAGE MEANS, TOTAL AMOUNT OF CURRENT OBTAINED AT EACH TIME
END OF OPERATION OF TOTAL CURRENT STORAGE MEANS

[FIG. 90]

CURRENT

TIME

[FIG. 91]

1 NET LIST

2 TEST VECTOR

3 LIBRARY

4 LOGIC SIMULATOR

5 EVENT INFORMATION

6 SIMULATION RESULT

8 CALCULATION RESULT OF CURRENT WAVEFORM

9 FFT PROCESSING SECTION

10 RESULT OF EMI ANALYSIS

11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION

12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT

13 CURRENT WAVEFORM AVERAGING SECTION

A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE

A9 LAYOUT DATA

G2 CHARACTERIZATION

G3 I-V TABLE OR I-V FUNCTION FOR EACH CELL

G4 LINE VOLTAGE DROP CALCULATION/INSTANTANEOUSLY-CHANGING CURRENT CORRECTION SECTION

[FIG. 92]

12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT

A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE

A9 LAYOUT DATA

B1 INFORMATION CONCERNING INSTANTANEOUSLY-CHANGING CURRENT FOR EACH INSTANCE

B2 EXTRACTION OF POWER NET

B3 CALCULATION OF ELECTRIC CURRENT FLOWING IN EACH SEGMENT

B4 INFORMATION CONCERNING EACH SEGMENT IN POWER LINE

B5 INFORMATION CONCERNING ELECTRIC CURRENT OF EACH SEGMENT

B6 CALCULATION OF RESISTANCE OF EACH SEGMENT
B7 CALCULATION OF VOLTAGE DROP IN EACH SEGMENT
B8 INFORMATION CONCERNING RESISTANCE OF EACH SEGMENT
B9 INFORMATION CONCERNING VOLTAGE DROP IN EACH SEGMENT
B10 CALCULATION OF VOLTAGE DROP IN EACH INSTANCE
B11 INFORMATION CONCERNING VOLTAGE DROP IN EACH INSTANCE
H1 CORRECTION OF ELECTRIC CURRENT
G3 I-V TABLE OR I-V FUNCTION FOR EACH CELL

[FIG. 93]
1 NET LIST
2 TEST VECTOR
3 LIBRARY
4 LOGIC SIMULATOR
5 EVENT INFORMATION
6 SIMULATION RESULT
8 CALCULATION RESULT OF CURRENT WAVEFORM
9 FFT PROCESSING SECTION
10 RESULT OF EMI ANALYSIS
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
13 CURRENT WAVEFORM AVERAGING SECTION
A9 LAYOUT DATA
I1 CHARACTERIZATION
I2 I-C-H TABLE OR I-C-H FUNCTION FOR EACH CELL
I3 LINE VOLTAGE DROP CALCULATION/INSTANTANEOUSLY-CHANGING CURRENT CORRECTION SECTION

[FIG. 94]
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
A6 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT TAKING INTO CONSIDERATION A DROP IN LINE VOLTAGE
A9 LAYOUT DATA
B1 INFORMATION CONCERNING INSTANTANEOUSLY-CHANGING CURRENT FOR EACH INSTANCE
B2 EXTRACTION OF POWER NET

B3 CALCULATION OF ELECTRIC CURRENT FLOWING IN EACH SEGMENT
B4 INFORMATION CONCERNING EACH SEGMENT IN POWER LINE
B5 INFORMATION CONCERNING ELECTRIC CURRENT OF EACH SEGMENT
B6 CALCULATION OF RESISTANCE OF EACH SEGMENT
B8 INFORMATION CONCERNING RESISTANCE OF EACH SEGMENT
B9 INFORMATION CONCERNING VOLTAGE DROP IN EACH SEGMENT
B10 CALCULATION OF VOLTAGE DROP IN EACH INSTANCE
B11 INFORMATION CONCERNING VOLTAGE DROP IN EACH INSTANCE
J1 CORRECTION OF ELECTRIC CURRENT
I2 I-C-V TABLE OR I-C-V FUNCTION FOR EACH CELL
D1 CALCULATION OF CAPACITANCE PROVIDED BETWEEN SEGMENTS
D2 INFORMATION CONCERNING A CAPACITANCE PROVIDED BETWEEN SEGMENTS

[FIG. 95]
1 NET LIST
2 TEST VECTOR
3 LIBRARY
4 LOGIC SIMULATOR
5 EVENT INFORMATION
6 SIMULATION RESULT
8 CALCULATION RESULT OF CURRENT WAVEFORM
9 FFT PROCESSING SECTION
10 RESULT OF EMI ANALYSIS
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
13 CURRENT WAVEFORM AVERAGING SECTION
A9 LAYOUT DATA
A10 I-V TABLE OR I-V FUNCTION FOR EACH CELL
A11 LINE VOLTAGE DROP CALCULATION/INSTANTANEOUSLY-CHANGING CURRENT CORRECTION SECTION
K1 COMPARISON/DETERMINATION

[FIG. 96]
TRIANGULAR WAVEFORM MODEL (TWENTY-THIRD EMBODIMENT)

[FIG. 97]
BLOCK DIAGRAM SHOWING CALCULATION OF A CURRENT WAVEFORM (TWENTY-THIRD EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
130 PEAK CURRENT LIBRARY
160 TRIANGULAR WAVEFORM HEIGHT CALCULATION SECTION
161 TRIANGULAR WAVEFORM WIDTH CALCULATION SECTION
162 TRIANGULAR WAVEFORM SHAPING SECTION

[FIG. 98]
FLOWCHART OF TRIANGULAR WAVEFORM SHAPING
1150 READ PEAK CURRENT LIBRARY
1161 PERFORM TRIANGULAR WAVEFORM SHAPING LOOP
1162 EXTRACT HEIGHT OF TRIANGULAR WAVEFORM OF OBJECT INSTANCE FROM PEAK CURRENT LIBRARY

[FIG. 99]
MULTI-ORDER-FUNCTION MODEL (TWENTY-FOURTH EMBODIMENT)

[FIG. 100]
BLOCK DIAGRAM SHOWING CALCULATION OF A CURRENT WAVEFORM (TWENTY-FOURTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
130 PEAK CURRENT LIBRARY
170 MULTI-ORDER-FUNCTION WAVEFORM HEIGHT CALCULATION SECTION
171 MULTI-ORDER-FUNCTION WAVEFORM WIDTH CALCULATION SECTION
172 MULTI-ORDER-FUNCTION WAVEFORM SHAPING SECTION

[FIG. 101]
FLOWCHART OF MULTI-ORDER-FUNCTION WAVEFORM SHAPING
1170 READ PEAK CURRENT LIBRARY
1171 PERFORM MULTI-ORDER-FUNCTION WAVEFORM SHAPING LOOP
1172 EXTRACT HEIGHT OF TRIANGULAR WAVEFORM OF OBJECT INSTANCE FROM PEAK CURRENT LIBRARY

[FIG. 102]
BLOCK DIAGRAM SHOWING CALCULATION OF A CURRENT WAVEFORM (TWENTY-FIFTH EMBODIMENT)
3 LIBRARY
5 EVENT INFORMATION
8 CALCULATION RESULT OF CURRENT WAVEFORM
11 INSTANTANEOUSLY-CHANGING CURRENT CALCULATION SECTION
12 CALCULATION RESULT OF INSTANTANEOUSLY-CHANGING CURRENT
130 PEAK CURRENT LIBRARY
181 WIDTH LIBRARY
180 GAUSSIAN FUNCTION WAVEFORM HEIGHT CALCULATION SECTION
182 GAUSSIAN FUNCTION WAVEFORM WIDTH CALCULATION SECTION
183 GAUSSIAN FUNCTION WAVEFORM SHAPING SECTION

[FIG. 103]
FLOWCHART OF GAUSSIAN FUNCTION WAVEFORM SHAPING
1180 READ PEAK CURRENT LIBRARY
1181 READ WIDTH LIBRARY
1182 PERFORM GAUSSIAN FUNCTION WAVEFORM SHAPING LOOP
1183 EXTRACT HEIGHT OF TRIANGULAR WAVEFORM OF OBJECT INSTANCE FROM PEAK CURRENT LIBRARY
1184 EXTRACT WIDTH OF OBJECT INSTANCE FROM WIDTH LIBARRY

[FIG. 104]
CURRENT
TIME

[FIG. 105]
FLIP-FLOP FF/Q

TOTAL SHORT CIRCUIT CURRENT
PEAK VALUE OF SHORT CIRCUIT CURRENT
TOTAL CHARGE CURRENT
PEAK VALUE OF CHARGE CURRENT

FLIP-FLOP FF/CK
TOTAL SHORT CIRCUIT CURRENT
PEAK VALUE OF SHORT CIRCUIT CURRENT
TOTAL CHARGE CURRENT
PEAK VALUE OF CHARGE CURRENT

BUFFER BUF/Y
TOTAL SHORT CIRCUIT CURRENT
PEAK VALUE OF SHORT CIRCUIT CURRENT
TOTAL CHARGE CURRENT
PEAK VALUE OF CHARGE CURRENT

[FIG. 106]
CURRENT
TIME

[FIG. 107]
START ACTIVATION OF TOTAL CURRENT CALCULATION MEANS
12501 READ CIRCUIT CONNECTION INFORMATION
12502 READ PATTERN OF SIGNAL CHANGE
12503 READ INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING IN ELEMENT
12504 IMPART A PATTER OF SIGNAL CHANGE TO CIRCUIT CONNECTION INFORMATION, TO THEREBY ENABLE PROPAGATION OF A SIGNAL. IN A CASE WHERE A CHANGE HAS ARISEN IN A SIGNAL APPEARING AT AN EXTERNAL INPUT TERMINAL OF A CIRCUIT ELEMENT, THE ELEMENT BEING DESCRIBED IN THE INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH AN ELEMENT, A RECTANGULAR WAVEFORM OF AN ELECTRIC CURRENT IS PRODUCED BY MEANS OF AVERAGING SHORT CIRCUIT CURRENT OF THE ELECTRIC CURRENT BY MEANS OF A PEAK VALUE THEREOF. A RECTANGULAR WAVEFORM OF AN ELECTRIC CURRENT IS

PRODUCED BY MEANS OF AVERAGING CHARGE CURRENT OF THE ELECTRIC CURRENT BY MEANS OF A PEAK CURRENT THEREOF. THE RECTANGULAR WAVEFORMS ARE ADDED TO THE INFORMATION CONCERNING THE TOTAL AMOUNT OF ELECTRIC CURRENT OBTAINED AT A TIME WHEN THE CHANGE HAS ARISEN IN THE SIGNAL APPEARING AT THE EXTERNAL INPUT TERMINAL.

12505 STORE, INTO TOTAL CURRENT STORAGE MEANS, TOTAL AMOUNT OF CURRENT OBTAINED AT EACH TIME

END OF OPERATION OF TOTAL CURRENT STORAGE MEANS

[FIG. 109]

1001 CIRCUIT CONNECTION INFORMATION STORAGE MEANS

1002 PATTERN-OF-SIGNAL-CHANGE STORAGE MEANS

1003 ELEMENT CURRENT STORAGE MEANS

1004 TOTAL CURRENT STORAGE MEANS

1005 TOTAL CURRENT CALCULATION MEANS

[FIG. 111]

TIME

[FIG. 112]

FLIP-FLOP FF

THE AMOUNT OF CURRENT FLOWING WHEN Y IS CHANGED

THE AMOUNT OF CURRENT FLOWING WHEN CK IS CHANGED

BUFFER BUF

THE AMOUNT OF CURRENT FLOWING WHEN Y IS CHANGED

[FIG. 113]

TOTAL CURRENT

TIME

[FIG. 114]

START ACTIVATION OF TOTAL CURRENT CALCULATION MEANS

1501 READ CIRCUIT CONNECTION INFORMATION

1502 READ PATTERN OF SIGNAL CHANGE

1503 READ INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING IN ELEMENT

1504 IMPART A PATTER OF SIGNAL CHANGE TO CIRCUIT CONNECTION INFORMATION, TO THEREBY ENABLE PROPAGATION OF A SIGNAL. IN A CASE WHERE A CHANGE HAS ARISEN IN A SIGNAL APPEARING AT AN EXTERNAL INPUT TERMINAL OF A CIRCUIT ELEMENT, THE ELEMENT BEING DESCRIBED IN THE INFORMATION CONCERNING THE AMOUNT OF ELECTRIC CURRENT FLOWING THROUGH AN ELEMENT, THE AMOUNT OF CURRENT APPEARING AT THE CIRCUIT ELEMENT IS ADDED TO THE INFORMATION CONCERNING THE TOTAL AMOUNT OF ELECTRIC CURRENT OBTAINED AT EACH TIME.

1505 STORE, INTO TOTAL CURRENT STORAGE MEANS, TOTAL AMOUNT OF CURRENT OBTAINED AT EACH TIME

END OF OPERATION OF TOTAL CURRENT STORAGE MEANS

[FIG. 115]

TIME

[FIG. 116]

O1 LAYOUT DATA

O2 LPE RULE

O3 LPE PROCESSING

O4 NET LIST

O5 TEST PATTERN

O6 SWITCH-SCALE CIRCUIT SIMULATION

O7 CURRENT WAVEFORM OF EACH TRANSISTOR

O8 MODELING OF CURRENT SOURCE

O9 MODELING OF CURRENT SOURCE ELEMENT

O10 LPE PROCESSING OF POWER LINE

O11 POWER LINE NET LIST

O12 TRANSIENT ANALYSIS SIMULATION

O13 RESULT OF CURRENT WAVEFORM

O14 FFT PROCESSING

O15 RESULT OF EMI ANALYSIS

O16 WIRE-LEAD FRAME IMPEDANCE

[FIG. 117A]
LOGIC VALUE
TIME

[FIG. 117B]
CURRENT
h = CURRENT (I) X 2/OUTPUT SLEW (W)
OUTPUT SLEW (W)
TIME

[FIG. 118]
1171 PATTERN-OF-SIGNAL-CHANGE STORAGE MEANS
1172 ELEMENT CURRENT STORAGE MEANS
1173 OUTPUT SLEW INFORMATION STORAGE MEANS
1174 CIRCUIT CONNECTION INFORMATION STORAGE MEANS
1175 CURRENT WAVEFORM CALCULATION MEANS
1176 CALCULATION RESULT OF CURRENT WAVEFORM

[FIG. 119]
FLOWCHART OF CALCULATION OF CURRENT WAVEFORM
1190 READ OUTPUT SLEW
1191 PERFORM TRIANGULAR WAVEFORM SHAPING LOOP
1192 EXTRACT BASE OF TRIANGULAR WAVE FROM OBJECT INSTANCE FROM OUTPUT SLEW

[FIG. 120A]
LOGIC VALUE
OUTPUT
TIME

[FIG. 120B]
CURRENT
TIME
OUTPUT SLEW
CURRENT (I) X 2 X RISE-DEPENDENT COEFFICIENT/OUTPUT SLEW (W)
CURRENT (I) X 2 X FALL-DEPENDENT COEFFICIENT/OUTPUT SLEW (W)

FALL-DEPENDENT COEFFICIENT = 2 - RISE-DEPENDENT COEFFICIENT

[FIG. 121]
1201 PATTERN-OF-SIGNAL-CHANGE STORAGE MEANS
1202 ELEMENT CURRENT STORAGE MEANS
1203 OUTPUT SLEW INFORMATION STORAGE MEANS
1204 CIRCUIT CONNECTION INFORMATION STORAGE MEANS
1205 CURRENT WAVEFORM CALCULATION MEANS
1206 CURRENT WAVEFORM STORAGE MEANS
1207 RISE-DEPENDENT COEFFICIENT/FALL-DEPENDENT COEFFICIENT STORAGE MEANS

[FIG. 122A]
LOGIC VALUE, DELAY
INPUT
OUTPUT
TIME

[FIG. 122B]
CURRENT
TIME
(CURRENT - CURRENT WHICH IS NOT DEPENDENT ON OUTPUT LOAD)X 2/OUTPUT SLEW
CURRENT WHICH IS NOT DEPENDENT ON OUTPUT LOAD X 2 / (DELAY - OUTPUT SLEW/2)
(DELAY - OUTPUT SLEW/2)/(NUMBER OF STAGES -1)
OUTPUT SLEW
TIME

[FIG. 123]
SLEW/CAPACITANCE CALCULATION MEANS
OUTPUT LOAD CAPACITANCE INFORMATION STORAGE MEANS
INPUT SLEW INFORMATION STORAGE MEANS
1221 PATTERN-OF-SIGNAL-CHANGE STORAGE MEANS
1222 ELEMENT CURRENT STORAGE MEANS
1223 OUTPUT SLEW INFORMATION STORAGE MEANS

1224 CIRCUIT CONNECTION INFORMATION STORAGE MEANS

1225 CURRENT WAVEFORM CALCULATION MEANS

1226 CURRENT WAVEFORM STORAGE MEANS

1227 ELEMENT CURRENT CALCULATION MEANS

1228 NON-LOAD ELEMENT CURRENT STORAGE MEANS

1229 NUMBER-OF-STAGES STORAGE MEANS

0964552 090500

Attorney's Docket No. 32796

COMBINED DECLARATION AND POWER OF ATTORNEY IN ORIGINAL APPLICATION

(Sole or Joint - Foreign)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD OF ANALYZING ELECTROMAGNETIC INTERFERENCE,

the specification of which

XX is attached hereto.

___ was filed on _____ as application Serial No. _____ and was amended on _____.

I hereby state that I have reviewed and understand the content of the above-identified specification, including the claims (Pearne, Gordon, McCoy & Granger Docket No. 32796), as amended by any amendment referred to above. I acknowledge my duty to disclose information of which I am aware which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119, of any foreign application(s) for patent or inventor's certificate listed below, and have also identified below any foreign applications for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

Country	Application Number	Filing Date (day/month/year)	Priority Claimed? Yes	No
Japan	P.Hei.11-196190	9/July/1999	XX	

I hereby designate the following as my mailing address and telephone number:

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and appoint each of the following as my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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